INTERNATIONAL
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INSTITUTE

Research Projects 2012

(For Crop Year 2011)

Interpretive Summaries

One of the strategic goals of the International Plant Nutrition Institute (IPNI) is to "facilitate research on environmentally responsible use of plant nutrients needed for agriculture to meet future global demand for food, feed, fiber, and fuel." We accomplish this objective through partnerships with colleges, universities, government agencies, and other institutions and organizations around the world where IPNI programs are established.

This past year we provided financial and in-kind support to over 156 projects around the world. Our scientists work closely with the researchers and cooperators carrying out the research … often assisting with the initiation, design, and implementation, monitoring of progress, and the interpretation and dissemination of results. The studies are diverse, including fertilizer best management practices, site-specific nutrient management, and other components of 4R Nutrient Stewardship in cropping systems, but increasing crop yields and productivity is a common objective with most of our research.

Projects typically run for 3 to 4 years, although we do support some longer-term studies. IPNI scientists compile short interpretive summaries highlighting key findings and progress of each project annually. This publication has the most recent updates. A complete history of interpretive summaries and other outcomes from our research is available online at our Research Database:

>**www.ipni.net/research<**.

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IPNI Interpretive Summaries 2012

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Note: The following are abbreviations and symbols for nutrients and related terms which appear routinely in the summaries. on the following pages.

N = nitrogen; P = phosphorus; K = potassium;
Mg = magnesium; S = sulfur; B = boron;
C = carbon; Ca = calcium; Cl^- = chloride; Cu = copper;
Fe = iron; Mn = manganese; Mo = molydenum;
Ni = nickel; Zn = zinc; ppm = parts per million; USD = United States dollar; INR = Indian rupees.

Special Projects

Best Management Practices for Sustainable Crop Nutrition in Bulgaria

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In 2008, a 5-year project was established in Bulgaria with the general goal of improving cultivation systems in Bulgaria's agriculture through efficient and sustainable use of plant nutrients. The project involves five Bulgarian organizations: The University of Forestry, Agricultural University, "Nikola Poushkarov" Institute of Soil Science, Executive Soil Resources Agency (Ministry of Agriculture), and the National Plant Protection Service (Ministry of Agriculture). About 50 researchers and discipline specialists take part in the project. Project activities include: 1) Evaluation of soil nutrient status through summarization of past national soil surveys and more recent localized regional surveys; 2) Systematic summarization of past relevant soil fertility research and identification of information gaps; 3) Nutrient omission/addition plot trials on target crops; 4) Development of tools for site-specific nutrient management that deliver updated recommendations to farmers and farmer advisers; and 5) Outreach activities to assure appropriate use of the developed tools.

After conducting a soil test survey of pilot regions and creating a GIS database with soil and field data attributes in 2009 and 2010, layers were created with low, medium, and high content of P and K. The emphasis in 2011 was in the Northwest and Southwest parts of Bulgaria where additional soil sampling was conducted to better assess the soil fertility tendencies of these regions. In 2009, an Access database was structured for past soil fertility research and to accommodate new project data. In 2010, data obtained from long-term crop field experiments after 1974 were entered into the database. The archive now consists of data from 87 experiments at 26 sites and 8 main soil types.

This (2011) was the third year of field omission/addition field plot trials (NPK or NPKMg as complete treatments). Crops tested were wheat, barley, maize, sunflower, potatoes, tomatoes, pepper, apricots, peaches, chokeberry, and vine grape. Results in 2011 in most cases confirm the tendencies found in previous years but at higher yield levels—most of the tested crops respond to fertilization with the NPK treatment producing the highest yields in many sites. Highly significant interactions among nutrients are being frequently measured with N responses (averaging close to 1 t/ha for wheat) larger than P and K responses for most crops. The project is well on its way to creating the foundation for new fertilizer best management practices for Bulgaria. *IPNI-14*

Nutrient Expert Development and Assessment

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This study was started in 2010-11 to evaluate through local partners the Nutrient Expert for Hybrid Maize (NEHM) in farmers' fields in Indonesia and the Philippines, and to develop, test, and refine new versions of Nutrient Expert (NE) for maize in new geographies (China, South Asia, and Africa) and NE for wheat in China and South Asia. Nutrient Expert for Hybrid Maize (NEHM)—developed in 2009 for favorable, tropical environments—has been adapted for maize growing conditions in South Asia, China, and Africa. NEHM recommendations were tested in farmers' fields (plot size ≥0.1 ha) against farmers' fertilizer practice (FFP) in Indonesia and the Philippines. Nutrient Expert for Wheat has been developed for winter wheat for South Asia and for winter wheat and spring wheat for China. Beta versions of NE wheat and NE maize are currently undergoing field testing and evaluation by regional IPNI and local partners in China, India, and Africa (Kenya and Zimbabwe). NE recommendations are tested against state recommendations (SR) and farmer's fertilizer practices (FFP). Development and evaluation of NE is conducted jointly with local partners and stakeholders.

During the 2010-11 maize cropping season, results from 22 farmers' fields across five sites in Indonesia showed that NEHM increased yield by 0.9 t/ha, which increased profit by USD 270/ha over FFP. Compared with FFP, NEHM recommendations reduced fertilizer P (-4 kg/ha), increased fertilizer K (+11 kg/ha), and did not significantly change fertilizer N. In the Philippines (with data from 31 fields across seven sites), NEHM increased yield by 1.6 t/ha and profit by USD 379/ha compared with FFP. Compared with FFP, NEHM gave higher rates of all three nutrients (+25 kg N/ha, +4 kg P/ha, and +11 kg K/ha), which substantially increased fertilizer costs (USD 64/ha) but still increased profit by about six times the additional investment in fertilizer. In 2011, beta versions of NE maize have been developed for South Asia, China, and Africa. *CR-01*

HarvestPlus Zinc Fertilizer Project

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BRAZIL: Agência Paulista de Tecnologia dos Agronegócios
CHINA: China Agricultural University
INDIA: Punjab Agricultural University
MOZAMBIQUE: Instituto de Investigacao Agraria de Mocambique
PAKISTAN: Pakistan Atomic Energy Commission
THAILAND: Chiang Mai University
TURKEY: Ministry of Agriculture
ZIMBABWE: University of Zimbabwe
SOFESCA: Soil Fertility Consortium for Southern Africa

Zinc deficiency is a global nutritional problem in crops and humans in many countries. Application of Zn-containing fertilizers offers a rapid solution to the problem complementing genetic solutions via plant breeding. This project was initiated in 2008 to evaluate the potential of various Zn-containing fertilizers to increase Zn concentration in cereal grains and improve crop production in various countries. In addition to IPNI, the project is supported by the HarvestPlus Biofortification Challenge Program, The Mosaic Company, K+S KALI, Omex Agrifluids, the International Fertilizer Industry Association, and the International Zinc Association.

Results to date have shown large variations among countries and within countries in response to Zn fertilization. Grain Zn concentrations have been significantly increased by foliar application of Zn, often doubling levels, while soil Zn applications have been less effective. The project, now in its second phase, will focus on experiments investigating changes in grain Zn concentration based on timing and rate of a single spray of foliar Zn fertilizer. *IPNI-10*

Global Maize

Global Maize Project in China: Liufangzi, Gongzhuling, Jilin Province

Project Leader: Kuan Zhang, Agricultural Environment and Resource Research Centre Jilin Academy of Agricultural Sciences, Beijing, Jilin. E-mail: xiejiagui@163.com

Project Cooperators: Jiagui Xie and Xiufang Wang

This long-term field experiment was initiated in 2009 in Liufangzi, Gongzhuling City, Jilin Province, where mono-cropping of spring maize is common. The aim of the experiment is to compare the performance of ecological intensification (EI) practices with common farmers' practice (FP) for yield and N use efficiencies. The main plot had two treatments: (a) EI treatment with 180-75-90-20-5 kg N-P_2O_5-K_2O-S-Zn/ha fertilizer application and (b) a FP treatment with 251-145-100 kg N-P_2O_5-K_2O/ha fertilizer application. Three sub-plots included: (a) N applied in all years (N all yr); (b) N applied in 2 of every 3 years (N 2/3 yr); and (c) no N applied any year (N 0 yr). In the year 2011, spring maize was planted on April 27 and harvested on September 24.

Ecological intensification treatment produced significantly higher grain yield (11.7 t/ha) than the FP treatment (11.1 kg/ha). Agronomic N efficiency (kg grain yield increase per kg N applied) was 42.3 kg/kg in the EI treatment and 29.2 kg/kg in the FP treatment. Similarly, partial factor productivity of N (kg grain yield per kg N applied) was 64.8 kg/kg with EI and 44.5 kg/kg with FP. EI with lower nutrient input obtained higher grain yield and nutrient use efficiency. Grain yield under N 2/3 yr treatment was significantly lower than under N all yr treatment, which demonstrated the value of N application in every spring maize growing season at the experimental site. *IPNI-20*

Global Maize Project in China: Dahe, Shijiazhuang, Hebei Province

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Project Cooperator: Chunjie Li

This long-term experiment was initiated in June 2009 in Hebei province. Summer maize was the first crop grown at this site, where winter wheat-summer maize rotation system is common. The main plot had two treatments: a) ecological intensification (EI) treatment with 120-60-80 kg N-P_2O_5-K_2O/ha fertilizer application in winter wheat and 150-40-50 kg N-P_2O_5-K_2O/ha in summer maize; and b) farmer's practice (FP) treatment with 225-120-50 kg N-P_2O_5-K_2O/ha fertilizer application in winter wheat and 300-135-0 kg N-P_2O_5-K_2O/ha in summer maize. Three subplots included: a) N applied in all 3 years (N all yr), b) N applied in 2 of every 3 years (N 2/3 yr), and c) no N applied (N 0 yr). Winter wheat was planted on October 19, 2010 and harvested on June 18, 2011, while summer maize (storage maize) was planted in the same plots on August 20, 2011 and harvested on October 12, 2011.

No significant difference in grain yields was found between EI and FP treatments for winter wheat, although higher N and P were applied in FP. However, agronomic N efficiency (kg grain yield increase per kg N applied) was higher in the EI treatment (13.3 kg/kg) than in the FP treatment (9.4 kg/kg). Similarly, partial factor productivity of N (kg grain yield per kg N applied) was considerably higher in the EI treatment (67.3 kg/kg) than in the FP treatment (37.7 kg/kg). Similar trends for grain yield and N use efficiencies were found in summer maize. N 2/3 yr treatment produced yields similar to N all yr treatment. This demonstrated that skipping N application in two seasons did not affect the grain yield during the third maize growing season. *IPNI-21*

Global Maize Project in India: Ranchi, Jharkhand

Project Leader: Rakesh Kumar, Birsa Agricultural University Department of Soil Science & Agricultural Chemistry, Kanke Ranchi, Jharkhand. E-mail: rkssacbau@rediffmail.com

Project Cooperators: A.K. Sarkar and S. Karmakar

Optimal nutrient management strategies for maize-wheat system were initiated in the Western Plateau Region of Jharkhand. Three experiments were conducted during 2011 with wheat (variety DBW 17) in rabi (December 2010 to April 2011) and maize (Pioneer 30V92) during kharif (June to October, 2011).

Highest grain yield of maize (7.0 t/ha) and wheat (4.1 t/ha) were obtained with application of N: P_2O_5:K_2O at 180: 90: 100 kg/ha for maize and 130: 70: 60 kg/ha for wheat under the ecological intensification (EI) treatment in the long-term system evaluation of EI and farmers' fertilization practices (FFP), Maize and wheat grain yields were 2.27 and 2.2 t/ha, respectively, under the FFP treatment. The EI treatment recorded 104.6 % higher maize equivalent yield over FFP.

Studies on the effect of rate and time of N application on maize-wheat system yield showed that application of N in maize at 240 kg/ha produced maximum grain yield (7.5 t/ha) that was at par with yield obtained (7.1 t/ha) with N application at 160 kg/ha in 3 splits on the basis of a leaf color chart (LCC). Nitrogen applied at 150 kg/ha in 2 splits in wheat resulted in highest grain yield (5.1 t/ha). Percent increase in yield of the maize-wheat system, over no application of N, was highest (254%) with the application of 240 and 150 kg N/ha in maize and wheat, respectively.

In the omission plot experiment, wheat yield was highest (4.8 t/ha) in the ample NPK (150:110:100) plot. Omission of N and P from the ample NPK treatment reduced yield by about 4 and 2.1 t/ha, respectively, with no reduction in yield due to K omission. In the following maize season, both ample NPK and omission plots were divided into two equal plots and residues of the previous wheat crop were retained in one plot and were completely removed from the other plot. Maize yield in the ample NPK (250:120:120) plots, with and without residues, were 8.36 and 8.28 t/ha, respectively. The lowest yield of maize (0.8 t/ha) was obtained in the N omission plot where wheat residues were retained while the yield was slightly higher (1.1 t/ha) in the N omission plot with no residues retained. Reduction in maize equivalent yield of the system due to nutrient omission, as compared to ample NPK plot, followed the order N (84.8%) > K (42.4%) > P (32.1%). *IPNI-22*

Global Maize Project in India: Maize-Wheat Cropping System in Northern Karnataka

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Project Cooperator: Y.R. Aladakatti, Associate Professor (Agronomy), Dharward

Evaluation of the maize-wheat cropping systems using ecological intensification (EI) with application of 180-90-100 kg N-P_2O_5-K_2O/ha and FP (farmer's practice) with application of 115-52-45 kg/ha resulted in maize grain yields of 3.9 t/ha and 2.8 t/ha, respectively. A 23% higher net return of INR 24,003/ha with benefit-to-cost (B:C) ratio of 2.67 was realized with EI than with FP. Grain yield of wheat using EI with application of 130-70-60 kg N-P_2O_5-K_2O and FP with application of 115-52-45 kg/ha was 4.1 t/ha and 3.2 t/ha, respectively.

Rate and application studies found that 240 kg N/ha application could generate 7.2 t/ha maize, which was higher than the 6.2 t/ha produced with 160 kg N/ha. Net returns and B:C ratios with 240 and 160 kg N/ha were INR 48,067 (3.76) and INR 41,206 (3.59), respectively. Application of N in three splits with and without the use of leaf color charts (LCC) resulted in equivalent maize yields of 4.9 and 4.7 t/ha, but these results were superior to N provided in two splits. Grain yields in the succeeding wheat crop were 4.2 and 3.6 t/ha using 150 and 100 kg N/ha, respectively. Application of N in three splits with and without the use of leaf color charts (LCC) resulted in equivalent wheat yields of 3.1 t/ha. However, the results were superior to N provided in two splits, which recorded a grain yield of 2.7 t/ha, respectively.

Studies on indigenous soil nutrient supply indicated ample NPK (250-120-120) and NPK rates derived through site-specific nutrient management (SSNM) (200-90-100) resulted in maize yields of 7.7 and 6.9 t/ha, respectively. Omitting N, P, and K from ample NPK resulted in a maize yield of 2.7, 6.1, and 6.6 t/ha, respectively. In wheat, ample NPK (150-110-100) and SSNM rates (120-60-50) produced 4.2 and 4.1 t/ha. Nitrogen, P, and K omission recorded a wheat yield of 1.8, 3.8, and 3.9 t/ha, respectively.

Considering the results obtained from experiments in the previous year, N rate for wheat in the EI treatment was slightly improved from 130 to 150 kg/ha. Soil and plant analysis have been carried out and the data on nutrient uptake is currently being compiled at the time of this report. *IPNI-23*

Global Maize Project in the United States: Ames, Iowa

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Project Cooperator: John Sawyer

The objective of this study is to determine whether or not an ecological intensification approach can increase yields more quickly over time than current farmer practice. The study design is a split plot. The main plot is management system: 1) farmer practice (FP), and 2) ecological intensification (EI). The split plot is: 1) N application according to the management system, and 2) no N. The treatments are in a randomized complete block, with four replications.

In 2011, there were no soybean grain yield differences between the systems (58.8 and 60.8 bu/A for FP and EI, respectively). For corn grain yield, the N application was significant between without and with N (138 and 221 bu/A for without and with N, respectively). There was no effect of management system nor was there an interaction between management system and N application. Therefore, the site was highly N responsive in both systems, but systems or differences in N source and application rate had no effect on corn yield (FP with N was 220 bu/A and EI with N was 222 bu/A). *IPNI-26*

Global Maize Project in Russia: N. Tselina, Rostov Oblast

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Project Cooperator: D.V. Bozhkov

Maize was grown in 2011 after winter wheat at both the A-site and C-site. The potential yield was determined at the A-site, and thus the respective yield gap. We accessed what practices and inputs needed to be modified to narrow the yield gap. The current grower practice and the Ecological Intensification (EI) management system were compared for the site. On-farm experiments (C-site) were used to facilitate fine-tuning of the management systems and getting them in place on farmers' fields. Initial soil properties indicate substantial soil nitrate (14.1 to 14.6 ppm in 0 to 20 cm layer), medium P extracted by a routine soil test (1% $(NH_4)_2CO_3$)—or "increased" (16 ppm P) according to new Olsen P soil-test interpretation classes proposed by researchers in Russia. The content of K extracted by 1% $(NH_4)_2CO_3$ was considered high, and the exchangeable K level was very high (373 to 387 ppm).

Grower fertilizer practice for maize (30 N 40 P) gave 8.12 t/ha grain at the A-site and "omission" of N fertilizer (9 N 40 P) resulted in 7.78 t/ha. No real zero N plots were tested since monoammonium phosphate (MAP) was used as a source of P. Ecological Intensification (EI) for maize (80 N 70 P 40 K) gave 8.77 t/ha, and "omission" of N (12 N 70 P 40 K) resulted in 8.33 t/ha. Grower fertilizer practice for soybean (20 N 40 P) gave 1.92 t/ha at the A-site, and "omission" of N fertilizer (9 N 40 P) produced 1.86 t/ha. In soybean, EI (30 N 45 P 30 K) gave 2.27 t/ha, while "omission" of N (10 N 45 P 30 K) led to 2.12 t/ha. Ecological Intensification for soybean also resulted in higher protein content in grain (46.7%) compared with N "omission"(43.9%)—generating a maximum protein output of 1,060 kg/ha. The highest yield of maize at the C-site (8.98 t/ha) was obtained with ample NPK rates (100 N 80 P 60 K) and the control treatment gave 7.45 t/ha. Thus, maize yield increased by 21% due to mineral fertilizer application. Nitrogen, P, and K fertilizer use at the C-site increased grain yield by 0.69 t/ha (8%), 1.05 t/ha (13%), and 0.56 t/ha (7%), respectively. Response to K fertilizer application indicates that perhaps soil-test K interpretation classes need to be adjusted and updated. *IPNI-41*

Global Maize Project in Mexico: Celaya, Guanajuato

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Project Cooperator: Benjamin Zamudio

The study was started in 2009 in Celaya, State of Guanajuato, Mexico, at 1,830 meters above sea level. The treatment design included a combination of two management systems (plant populations) (Farmers' practice [FP] and a higher population [EI]) and three N fertilization regimes (0-N, 300 kg N/ha applied two out of three years, and 300 kg N/ha applied every year). In 2011, the six treatments were: 1) 120,192 seeds/ha, 0-N; 2) 120,192 seeds/ha, 300 kg N/ha (0 N in 2009; 300 kg N/ha in 2010); 3) 120,192 seeds/ha, 300 kg N/ha (300 kg N/ha applied both in 2009 and 2010); 4) 90,580 seeds/ha, 0-N; 5) 2) 90,580 seeds/ha, 300 kg N/ha (0-N in 2009; 300 kg N/ha in 2010); 6) 90,580 seeds/ha, 300 kg N/ha (300 kg N/ha applied both in 2009 and 2010). The first three treatments are considered as an intensification of the last three, which represent the traditional farmers' practice.

Yields responded to N, regardless of its application sequence. The application of 300 kg N/ha increased grain yields from an average of 1.9 t/ha to 10.9 t/ha, a reflection of significantly greater Harvest Index, more ears/ha, and larger ears with heavier kernels. Partial Factor Productivity and Agronomic Efficiency were 36 and 30 kg grain/kg N, respectively. No significant differences in grain yield could be detected between the intensive and traditional management options, although plant population at harvest differed significantly between them: 91,600 vs. 68,900 plants/ha, respectively. By harvest time, the plant population under both management systems had decreased by 24% on average, which is higher than normal, especially under experimental conditions. Most of that loss (15%) had taken place by the third week after crop planting. *IPNI-28*

Global Maize Project in Mexico: Toluca, México

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The study was started in 2009 in Toluca, State of México, at an altitude of 2,370 meters above sea level. The objective was to compare the effects of six combinations of plant populations and fertilizer applications. Half of the treatments—labeled as intensive management—included high plant populations and the application of a complete fertilizer formula (90 kg P_2O_5/ha, 90 kg K_2O/ha, 44 kg MgO/ha, 50 kg S/ha, and 3 kg Zn/ha). The remaining treatments were similar to current farmers' practices with regards to plant

population and fertilizer application (30 kg P_2O_5/ha and 30 kg K_2O/ha). Three N fertilizer application regimes were combined with the management systems just described: 0-N, 300 kg N/ha applied two out of three years, and 300 kg N/ha applied every year with the intensive management, and 0-N, 180 kg N/ha applied two out of three years, and 180 kg N/ha applied every year, with the farmers' management.

The 2011 season was very bad, with lack of rain at the beginning; followed by flooding, hail storms, and a devastating early frost in the first week of September. The yield levels were therefore lower than in the previous years. Yield under intensive management (3,594 kg/ha) was significantly higher than under traditional management (2,699 kg/ha). This result mirrored the differences in plant population at harvest: 80,208 and 62,691 plants/ha in the intensive and farmers' management treatments, respectively. Under intensive management, yields with N (3,906 kg/ha) were 31% higher than without N (2,971 kg/ha), whereas no significant effects from N could be detected under the traditional management. Partial Factor Productivity was low under both management systems: 12 and 15 kg grain kg/N, for intensive and traditional, respectively. Likewise, agronomic efficiency was extremely low (3 kg grain/kg N for both management systems). *IPNI-29*

Global Maize Project in Brazil: Itiquira, Mato Grosso

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Cropping system intensification will be necessary to meet the future demand for corn (maize). Ecological Intensification (EI) seeks cereal production systems that satisfy future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project (GMP) was established to identify gaps in yield between current technology and improved technology aimed at achieving EI. The experiment was initiated in November 2009 at Itiquira, Mato Grosso in an Oxisol site that has been under cultivation for 20 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots involving three levels of N input plus a control. The types of cultivation being evaluated are: (1) farmer practice (FP) of soybean followed by corn; (2) FP + a forage crop (Brachiaria decumbens) in the winter; and 3) EI involving a 3-year complete crop rotation cycle of soybean, corn (second crop), forage, soybean, crotalaria, regular corn, and forage. The EI treatment occurs three times, alternating the initiation point of the crop rotation to permit the production of corn every summer. The levels of N input were 50, 100, and 150 kg N/ha for the first corn crop (summer crop) or 30, 60, and 90 kg N/ha for the second corn crop, plus a control with no N added in both cases.

The results to date indicate: (a) there were good responses to N in both corn crops, which positively influenced yields and total N uptake, (b) the addition of N positively impacted the dry-matter yield of the forage grass cultivated with corn, (c) soybean grain yield was higher when cultivated after corn second crop + forage than when cultivated only after corn, showing a positive effect of Brachiaria in the system, and (d) soybean crop responded to N previously applied to corn, showing that for high soybean yields N biological fixation may not be enough. This is a long-term project intended to influence current opinions on how to best manage cereal production in the region. *IPNI-18*

Global Maize Project in Brazil: Ponta Grossa, Paraná

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Cropping system intensification will be necessary to meet the future demands for corn. The proposed system of Ecological Intensification (EI) seeks cereal production systems that satisfy these future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project was established to identify gaps in yield between current technology and improved technology aimed at achieving EI.

The experiment was first established at Ponta Grossa, Paraná, in May 2011, by seeding the winter crops to the respective treatment plots. The soil in the area is an Oxisol that has been in a no-till system for 6 years. The experiment had a split-plot design with the main plots involving three types of management systems and the sub plots being three levels of N input plus a control. Different management systems used were: 1) farmer practice (FP) involving a 2-year complete crop rotation cycle of black oats, corn, wheat, and soybean; 2) FP + silage production; and 3) EI of black oats + forage peas, corn, black oats, and soybean. The EI treatment is planned to occur twice, alternating the crop rotation initiation point to permit the production of corn every summer. The levels of N application for the corn were 70, 140, and 210 kg N/ha, plus a control with no N added.

The results for dry-matter yield for the winter crops varied from 3,907 for black oats to 5,725 kg/ha for ryegrass. Up to 140 kg/ha of N were applied to the soil for growing winter crops. The summer crops are currently in the area, and it is possible to visualize the effect of the winter forage peas through their addition of N to the system (lower N response in the corn crop). Soil samples were collected to evaluate the soil physical properties. Also, tissue samples were collected from the summer crop for laboratory analysis. *IPNI-19*

Global Maize Project in Argentina: Balcarce, Buenos Aires

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Project Cooperators: Guillermo Studdert, Aníbal Cerrudo, Roberto Rizzalli, Pablo Barbieri, Hernán Echeverria, Liliana Picone, Cecilia Videla, José Luis Costa, Virginia Aparicio, and Pablo Abbatte

A long-term field experiment was established at Balcarce, Buenos Aires, in the 2009/10 growing season. The crop rotation is maize-wheat/double cropped-soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and Ecological Intensification practice (EI). Treatments differed by either cultivar, planting date, pest and weed control, or nutrient management practices.

Maize and wheat crops in the 2010/11 season developed under adequate climatic conditions, which favor the expression of an improved potential yield in the EI treatments. Maize yields were 12,647 kg/ha, and 14,726 kg/ha for the FP and EI treatments, respectively, a significant difference of 16% ($p<0.002$). Wheat yields were 3,141 kg/ha for FP and 4,745 kg/ha for EI, again with significant differences between treatments ($p<0.007$). Double cropped-soybean was planted immediately after the wheat harvest in January, and yields of 1,361 kg/ha and 1,165 kg/ha were obtained under the FP and EI treatments, respectively, without significant differences between treatments.

Considering the first 2 years and the three crops involved in the maize/wheat/double cropped soybean, the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP, but the two treatments did not differ much in the capture of water (ratio of ET/total precipitation). The EI treatment also showed higher N use efficiency and N removal and less negative N balances, but lower partial factor productivity of N as compared to the FP treatment. *IPNI-24*

Global Maize Project in Argentina: Oro Verde, Entre Ríos

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Project Cooperators: Ricardo Melchiori, Pedro Barbagelata, Carolina Sasal, Hugo Tassi, and Osvaldo Paparotti

A long-term field experiment has been established at Oro Verde (Entre Ríos) in the 2009/10 growing season. The crop rotation is maize-wheat/double cropped-soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and ecological intensification practice (EI). Treatments differed in either cultivar, planting date, pest and weed control, or nutrient management practices.

Maize yields showed an excellent response to the EI treatment with 5,787 and 9,287 kg/ha yields for the FP and EI treatments, respectively—a significant difference of 60%. Wheat yields were affected by rust (Puccinia triticiae) and were 3,792 and 3,249 kg/ha yields for FP and EI, respectively, with significant differences between treatments. On the other hand, double cropped-soybean yields were similar for both treatments and were 3,128 and 3,123 kg/ha under the FP and EI treatments, respectively.

Considering the first 2 years and the three crops involved in the maize/wheat/doublecropped soybean, the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP, but the treatments didn't differ much in the capture of water (ratio of ET/total precipitation). The EI treatment also showed higher N use efficiency and less negative N balances, but lower partial factor productivity of N when compared with the FP treatment. *IPNI-25*

Global Maize Initiative, Colombia

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Project Cooperators: Henry Vanegas (FENALCE General Manager), Carlos E. Molina, and Gustavo Lemos

In 2011, this study completed four consecutive crop cycles at Villa Escocia, and the fifth cycle was planted on October 27. The study had following specific objectives: 1) measure yield differences among different nitrogen management strategies and 2) compare the ecological intensification (EI) management against traditional maize technology.

In 2009-B, the first planted cycle, the average yield in the intensive management was 7.30 t/ha and the traditional management yield average was 5.49 t/ha. Only the treatment with intense management with N in all cycles showed a significantly higher yield (8 t/ha), but this was possibly an artifact as many other treatments suffered from plant lodging. Overall, this cycle indicated a high fertility soil, with small differences within N strategies tested with high or low planting densities.

Cycle 2010-B showed the lowest yield overall as a result of extreme rainfall, this was also the cycle in which the treatments with reduced N application (2/3 cycles) did not receive N. The average grain yield in 2010-B with intensive management was only 6.45 t/ha, while the traditional management average was 5.53 t/ha. The maximum yield was obtained with traditional management N applications in all cycles (8.77 t/ha), which was slightly higher than intensive management with N in all cycles (8.45 t/ha). It was noticeable by this time a carry-over effect with N management strategies, those treatments with no N or reduced applications (2/3 cycles) had significantly lower yields than N repeated in all cycles.

In the other two crop cycles (2010-A, and 2011-A), the treatments with N application and higher planting density had the highest yields followed by the treatments with N application and low planting density. The values of yield with no N applications declined progressively across the four consecutive crop cycles. *IPNI-38*

Americas and Oceania Group:

North America

Northeast Region: Dr. Tom Bruulsema

Delaware

Evaluating Nitrogen Sources for Corn on the Delmarva Peninsula

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Numerous corn fields showed visual symptoms of S deficiency in the past 5 years, and in 2009 corn yield climbed more than 50 bu/A in response to applied S. In 2010, five studies compared N sources including ammonium sulfate and ammonium sulfate nitrate (ASN) at sites in Delaware and on the Eastern Shore of Maryland. These studies also included urea, polymer-coated urea, urea ammonium nitrate (UAN), and forms of urea with inhibitors of urease and nitrification.

Growing conditions in 2010 were extremely hot and dry, especially from June through early July. A local farmer noted, “In the thirty-some years that I’ve been farming, I’ve never experienced a year with such a long period of day-after-day intense heat and no rain.” Drought conditions at the three non-irrigated sites led to smaller-than-expected responses to N in general and no significant differences among N sources. However, inclusion of S in the N source increased grain S at all three locations, and alleviated visual symptoms of S deficiency at one of the three. The lack of superior response to enhanced-efficiency forms of N is consistent with expectations, since there was little opportunity for N loss in the dry growing conditions.

At two irrigated sites, one showed no differences among N sources, and at the other either dribble-band UAN with urease inhibitor or broadcast ASN at sidedress produced yields 18 to 31% higher than either a UAN knife treatment or urea broadcast at sidedress. SuperU (urea with inhibitors of urease and nitrification) also performed well. Further evaluation of the results will continue after plant tissue analysis is completed. In the 2011 season, ammonium sulfate nitrate performed very well in comparison to other N sources, and there was evidence suggesting that part of the cause was a response to the S in the material. *DE-05F*

Michigan

Evaluating Sulfur in Michigan Corn Nitrogen Programs

Project Leader: Kurt Steinke, Michigan State University, East Lansing, MI. E-mail: ksteinke@msu.edu

Corn growers in Michigan, like those elsewhere, seek to improve yields and N use efficiency at the same time. With declining deposition of S from the atmosphere, it is appropriate to evaluate the role of N sources that also supply S. This study evaluated 3 N sources, at 2 rates and 2 application timings. Owing to a rainy spring, planting was delayed to 24 May, four weeks after the pre-plant application had been made. Four inches of rain fell between pre-plant application and planting. Higher than normal rainfall occurred during the growing season as well.

Visual observations, plant analysis and yields all confirmed that pre-plant applications supplied less N to the crop than sidedress applications. Yields with sidedress applications averaged 188 bu/A, 8% higher than those with pre-plant application. Source differences were small, but ammonium sulfate and ammonium sulfate nitrate tended to produce higher yields than urea at the rate of 150 lb N/A, while at the 100 lb N/A rate ammonium sulfate produced lower yields than ammonium sulfate nitrate or urea. The results highlight how crop responses to N source and timing can depend on weather. They underscore the need to time applications and choose sources to suit site-specific and year-specific growing conditions. *MI-12F*

New York

Comparison of Tissue Potassium and Whole Plant Potassium for Alfalfa

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Price increases for K fertilizers in recent years triggered many New York alfalfa producers to ask if K applications can be reduced without impacting yield, quality, or stand survivability. This study compared tissue sampling, whole-plant K levels, and soil test K levels as potential diagnostic criteria that could be used to fine-tune K recommendations.

In 2010, tissue samples taken of the top 6 inches of plants appeared similar to whole plant samples for K concentrations, with a 1:1 relationship across a wide range of K rates. In this experiment, tissue K levels reached 2% at a soil test K level of about 140 ppm. These results suggest that farmers can use the whole-plant analysis of their forage as an indicator of K sufficiency that can supplement soil test information.

This project included a 5-year experiment at the research station in Aurora, New York. In it, a residual effect of previous manure application was detected, even though the last application had been 5 years earlier. This showed that N-based manure management for silage corn can leave large amounts of residual K in soils. In this experiment, tissue K concentrations were not related to yields, and there were indications that other yield-limiting factors limited the response to the K applied each year in the spring starting in the second year of the stand. Yields ranged widely with previous history of the soils, with much higher yields on plots that had a history of manure or compost applications. Further data have been collected from plants and soils in the on-farm trials and will be reported on in the coming year. *NY-09*

Beta-testing the Adapt-N Tool in On-farm Strip Trials

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Project Cooperators: Bianca Moebius-Clune and Jeff Melkonian

This project aims to increase adoption of adaptive N management for corn production using better rates and timing of application. The new Adapt-N tool provides N fertilizer recommendations adapted to the spring rainfall and temperature conditions of the current season, using high-resolution weather data, a sophisticated computer model, and field-specific information on soil properties and soil and crop management.

Based on experiences from past years, it is clear that a larger number of replicated strip trials are needed from multiple growing seasons. The objectives are to 1) further validate the Adapt-N tool for on-farm use, and 2) promote grower adoption of Adapt-N as part of their tool kit for adaptive N management. The main hypothesis is that the Adapt-N tool provides more accurate estimates of the current season's optimum N rate than conventional methods and tools.

Strip trials are planned to provide consultants (Dave DeGolyer, Western NY Crop Management Association) and Cornell Cooperative extension collaborators with the opportunity to learn how to use the tool in depth and understand its outputs enough to communicate with their growers about it. Farmers and crop advisers will also learn about N dynamics, and will receive help with safely testing this unique new tool. The overall outcome goal is more effective and efficient N management, thereby benefitting farmers, society, and the environment. *NY-10*

Ohio

Impact of Phosphorus and Potassium Fertilization and Crop Rotation on Soil Productivity and Profitability

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Project Cooperator: Edwin Lentz

Growers in the eastern U.S. Corn Belt often fertilize the whole rotation rather than the individual crops. Typically, in the fall prior to corn planting, farmers supply enough P and K to satisfy the nutrient needs of both corn and the following soybean crop. This practice has proven to be a viable option for corn-soybean (CS) rotations on soils with adequate nutrient levels, but questions arise for producers in a 3-year rotation of corn-corn-soybean (CCS). In 2006, studies assessing P and K fertilization strategies were started in three locations. Two rotations were compared: corn-corn-soybean, and corn-soybean. These rotations were

fertilized by broadcast application following soybeans and prior to fall tillage, at P and K rates corresponding to zero, once, and twice the crop removal for the rotation.

With the 2011 season, this trial has run 6 years: two cycles of the CCS rotation and three cycles of the CS rotation. For purposes of testing the soil test calibration, this provides a total of 36 site-rotation-years of high-quality data. Average yields for some site-years have been as high as 242 bu/A for corn and 68 bu/A for soybeans. Responses to the fall broadcast applied P and K have been as expected with respect to the critical soil test levels of the tri-state soil fertility recommendations used in Ohio. Soil test P levels ranged from 16 to 39 ppm by the Bray-P1 test (above the critical level of 15), so large responses to P were neither expected nor observed. An economic response frequency of 12 out of 28 site-years provides strong justification for applying P as recommended in the maintenance range. Soil test K levels ranged from 84 to 272 ppm, extending from well below the critical level to well above the maintenance limit. Yield responses to applied K as large as 16% were seen in soils testing below the critical level. These results suggest that the current critical values and maintenance limits for soil test P and K are still appropriate for today's higher-yielding corn and soybean crops, provided that appropriate adjustments to maintenance rates are made to match the higher removal rates of these nutrients. *OH-16F*

Ontario

Long-term Optimum Nitrogen Rates for Corn Yield and Soil Organic Matter in Ontario

Project Leader: Bill Deen, University of Guelph Dept of Plant Agriculture, Guelph, ON. E-mail: bdeen@uoguelph.ca

Project Cooperators: John Lauzon and Greg Stewart

Decisions on optimum N rates are often made on the basis of single-year responses. Data are limited on the long-term impact on productivity and soil organic matter of rates higher or lower than these short-term optima. This controlled experiment was designed as a base for testing the application of dynamic soil-crop-atmosphere models as predictors of N rates for corn that optimize sustainability. The specific objectives include: 1) assessment of short and long-term effects of N rate and application timing on productivity, environmental impact, profitability, and cropping system sustainability; and 2) validation of crop models, such as *Hybrid-Maize*.

The 2009 growing season was the first in which treatments were applied. Economically optimum rates of N were 15% higher than recommended for the pre-plant application, and 32% higher than recommended for the side-dress application, possibly because of a relatively cool, wet, and long growing season. Corn grain N concentration was 0.60 to 0.66 lb/bu at rates of N sufficient for maximum economic yield. Residual soil nitrate increased sharply when N rates exceeded the economic optimum, and were higher for side-dress than for pre-plant N applications. Favorable growing conditions in 2010 resulted in high yields, 195 bu/A at an optimum N rate of 190 lb/A, more than 50% higher than recommended. At this optimum rate, partial N balance (PNB) was 63% and recovery efficiency (RE) of N was 54%. Neither application timing nor duration of N treatment produced significant differences in optimum rate. Soil residual nitrate-N at harvest was about 10 lb/A higher at the optimum rate compared to the recommended rate, but was not affected by application timing or duration of treatment.

In 2011, yields were 175 and 171 bu/A for at-plant and sidedress N applications, respectively. Corresponding optimum N rates were 185 and 162 lb/A, again well above currently recommended rates. Responses to N did not differ between long-term and short-term rates. Recovery efficiencies of applied N ranged from 56% to 61%. Soil nitrate levels at corn maturity did not differ among any treatments.

This project also receives support from the Ontario Agri Business Association, for sampling soil residual nitrate and soil organic carbon, and from the Canadian Fertilizer Institute, for measuring nitrous oxide emissions. This additional support enables a more complete assessment of sustainability. *ON-29*

Corn Hybrid Interactions with Nitrogen and Foliar Fungicides

Project Leader: David Hooker, University of Guelph, Ridgetown, ON. E-mail: dhooker@execulink.com

Project Cooperators: J.D. Lauzon, W. Deen, T. Tenuta, G.A. Stewart, and K. Janovicek

Growers have shown interest in corn hybrid differences in response to applications of fungicide and N. Fungicides can potentially improve N use efficiency by delaying leaf senescence and enhancing the "stay-green" physiological mechanism. This project aims to determine the potential for yield improvement through exploitation of hybrid-fungicide-N interactions. Field trials implemented at three sites in southwestern Ontario compared six hybrid pairs (triple-stacked with corn rootworm resistance versus Roundup-Ready-only isolines) at five N rates with two fungicides (Headline and Proline) and a non-fungicide control.

Results in 2010 from two of the three sites showed strong evidence of hybrid-by-N interactions, and some evidence of hybrid-by-fungicide interactions. The highest yield of 224 bu/A was produced by the Pioneer hybrid 35F44 (a triple-stack) with Headline fungicide and N applied at 120 lb/A. The triple-stacked trait in general, however, did not have much influence on N use efficiency. The fungicides interacted only slightly with N rate, tending to increase both optimal rates and yields by about 2%. Dry growing conditions near the end of the season may have limited the expression of the stay-green trait.

Good results were obtained in 2011 from all three sites. Despite a rainy spring that delayed planting until June, peak yields at all 3 sites exceeded 200 bu/A, approaching 250 bu/A at one of the sites. The study provided clear evidence that yield response to N varied among corn hybrids, but was not correlated to the corn rootworm resistance or 'triple-stack' trait. Responses to fungicide application averaged 3 to 4 bu/A and did not depend on N rate. Analysis of plant and grain uptake and concentrations remains to be completed. Further studies exploring ways to improve yield along with NUE will build on the foundation of findings from this study. *ON-30*

Virginia

Evaluation of Ammonium Sulfate Nitrate in Virginia Snap Bean Production

Project Leader: Mark Reiter, Virginia Tech Eastern Shore AREC, Painter, VA. E-mail: mark.s.reiter@gmail.com

Fresh-market snap beans occupy 5,500 acres in Virginia. Producers are interested in exploring sources and rates to improve N use efficiency. This trial compared five N sources (urea with dicyandiamide, ammonium nitrate, calcium nitrate, ammonium sulfate-nitrate, and urea-ammonium nitrate) at three rates.

In 2009, for spring-grown beans, urea with dicyandiamide increased yield by 25% over the control, while the other sources did not. For fall-grown beans, all N sources increased yield by 56% over the control, with an optimum N rate of 80 lb/A, and reduced symptoms of common rust *(Uromyces appendiculatus)*. In 2010, an abnormally dry and hot summer hampered snap bean growth and as a result yields did not increase beyond 40 lb N/A. All N sources increased yields to a similar degree, except ammonium nitrate, which did not increase yields over the check. There were no responses to S applied either as gypsum or as ammonium sulfate-nitrate. In 2011, dry weather in May followed by an intense rainstorm in June resulted in poor yields and no response to applied N in spring beans. The fall beans responded positively to N but not to S. Ammonium sulfate-nitrate, urea, and urea with dicyandiamide produced higher yields than urea-ammonium nitrate or ammonium nitrate. Grade quality was not influenced by N source. These findings support N management decisions that optimize food yields while minimizing risk of water contamination by N on the sandy loam soils of the Chesapeake Bay watershed. *VA-22F*

Evaluation of Ammonium Sulfate Nitrate in Virginia Sweet Corn Production

Project Leader: Mark Reiter, Virginia Tech Eastern Shore AREC, Painter, VA. E-mail: mark.s.reiter@gmail.com

Virginia farmers grow over 3,000 acres of fresh market sweet corn. They are interested in exploring sources and rates to improve N use efficiency. This trial compared three N sources (urea-ammonium nitrate, ammonium nitrate, and ammonium sulfate-nitrate) at three rates. The first two N sources were compared with and without S, applied as gypsum, at a rate designed to supply the equivalent amount of S provided by ammonium sulfate-nitrate (65 lb/A).

Averaged over two seasons (2009 and 2010), the three N sources increased marketable yields by 30 to 65% using optimum N rates ranging from 110 to 170 lb/A. Agronomic efficiency at optimum rates ranged from 26 to 45 lb of marketable yield increase per lb of N applied. Sulfur added as gypsum did not increase yields, and sources did not show consistent differences across the two seasons. In 2011, excessive heat during silking caused limited kernel set and thus marketable yields were zero. Application of N increased total yield, but the small differences among sources are unlikely to mean anything for years in which a marketable yield is achieved. For this reason, another year of testing these sources is advised. These findings support N management decisions that optimize food yields while minimizing risk of water contamination by N on the sandy loam soils of the Chesapeake Bay watershed. *VA-23F*

Sulfur Fertility for Barley Production in the Mid-Atlantic

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Project Cooperators: Wade Thomason, David Moore, and Keith Balderson

Virginia consistently produces approximately 69,000 acres of barley per year. As with any grain, S fertility recommendations need to be established to ensure adequate supply for producing high yields. Sulfur fertilizer applications have become an important consideration for farmers in the mid-Atlantic utilizing sandy loam soils, since S deposition from the atmosphere has declined as a result of air pollution controls. We conducted a S source × S rate study to determine if S fertilizer applications were necessary.

At the two sites in 2011, the first year of the study, application of S boosted yields by 17% to an average of 96 bu/A. Using ammonium sulfate as a source produced 8% higher yields, on average, than either ammonium-sulfate nitrate or a combination of urea-ammonium nitrate and ammonium thiosulfate. Of the three S rates compared, from 10 to 30 lb/A, the lowest rate was sufficient for highest quality grain and highest yields. *VA-24F* ❖

Americas and Oceania Group

North America

Northern Great Plains Region: Dr. Tom Jensen

Alberta

Evaluation of Phosphate and Nitrogen Fertilizers Treated with Polymer Additives to Increase Fertilizer Efficiency

Project Leader: Dick Puurveen, University of Alberta Sustainable Resources Department, Edmonton, AB.
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Project Cooperators: Claire Langlois, Guy Lafond, and Brian Hellegards

This project consisted of two experiments, one at Willingdon, Alberta comparing P fertilizer sources; and another at Dapp, Alberta comparing N fertilizer sources. This study was initiated in April 2008 making this the fourth year of experiments conducted by the University of Alberta.

In the P experiments, 13 treatments compared two P fertilizer products [granular monoammonium phosphate (11-52-0) and liquid polyphosphate (10-34-0)], three P rates (9, 18 and 27 lb P_2O_5/A), and P fertilizer product with and without the Avail® fertilizer additive. A check treatment (no P fertilizer) was included to determine the overall response to the addition of P. Unfortunately, there appeared to be no response to P at the site, and because of adverse cool and excessive moisture conditions affecting germination and seedling establishment. There was no observable difference between the two P fertilizer products, rate of P, and whether Avail® was added or not.

In the N experiment, an experimental design was used to compare three forms of N (urea, ESN® urea, and Nutrisphere®-treated urea), and four rates of N (22, 44, 88 and 132 lb N/A). All N fertilizer was side-banded at planting. A check or zero N treatment was included in each replicate to assess N response. The coefficient of variation (CV) was high for the site, i.e. 24.5%, due to uneven flooding adversely affecting plant stands over the plot area. There was a moderate response to N observed with the 88 and 132 lb N/a rates significantly out yielding the zero N treatment average. There was no difference between the 88 and 132 lb N/A rates due to lodging in the plots of the 132 lb N/A rate. There was no observable difference between N forms except at the 88 lb N/A rate where ESN and Nutrisphere N resulted in higher yields compared to regular urea. *AB-26F*

Large Urea Granules for Broadcast Application in No-till Barley Cropping

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This is the third year of an experimental study that was initiated to evaluate the potential use of two technologies for broadcast urea granules prior to no-till planting of small grain cereals in the Northern Great Plains region of North America. This is seen as a possibility to allow N application with less energy required during planting compared to banding N at planting. The two technologies being evaluated are: 1) the size of the urea granules, comparing regular size granules (approximately 3 mm, or 1/8 in.) to large forestry grade granules (approximately 10 mm or 1/2 in.) and 2) adding urease inhibitor, and or a urease plus nitrification inhibitor to the granules. One additional experimental factor is the timing of application, which being in the mid-fall, compared to early spring, and at planting. There are two control treatments included in the study. One is a zero N treatment in order to determine the N response at the site, and the other is a common farmer practice of side-banding N fertilizer during the planting operation, or so-called “double-shoot planting”. All rates of N were 62 lb N/A, which is sub-optimal, but chosen to hopefully show potential differences between experimental factors. The research experiment was conducted at the University of Alberta (AB) Research Farm at Ellerslie, AB. Spring barley was no-till planted on April 27, 2011. The 2011 growing season was very wet and cool during May, but warmed up for June, July and August. Moisture was adequate, but not excessive precipitation. Barley was harvested on September 8, 2011.

All the broadcast urea treatments with large or regular sized granules, and with or without addition of an urease inhibitor, or an urease inhibitor plus a nitrification inhibitor, yielded similarly to the common farm practice of side-banding urea during planting. The side-banding treatment yielded an average of 73 bu/A. This

site experiment had excessive spatial variability with a coefficient of variance (CV) of 20.3%. There was an overall response to added N with the control or zero-N treatment yielding only 65 bu/A, while some of the N treatments yielded up to 90 bu/A. It is planned to continue this experiment for one more growing season. *AB-27*

Large Urea Granules for Broadcast Application in No-till Spring Wheat

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Project Cooperator: Ross McKenzie

This is the second site-year for this experiment. In 2010, the experiment was severely flooded, and this is the first year of analyzable data. The control zero N treatment yielded 43 bu/A, with the highest fertilizer treatment yielding 71 bu/A. The site was quite variable with a coefficient of variation (CV) of 15%. All of the fertilizer treatments were applied with a sub-optimal N rate (63 lb N/A) because emphasis of this experiment was to compare timing, i.e. fall versus spring; size of urea granule, i.e. regular sized urea (1/8 in.) vs. large of the urea granule (1/2 in.); and whether or not adding an urease inhibitor (Agrotain®) resulted in greater yields. All of the N fertilizer treatments resulted in similar yields statistically. There didn't appear to be any advantage or disadvantage of using a larger sized granule as the 1/2 in. granules performed just as well as the regular 1/8 in. granules. There was no statistical yield disadvantage to fall application compared to spring application, or adding Agrotain to the urea, but there did appear to be a trend towards higher yields in the spring applications, and with application of Agrotain. There was 3 in. of precipitation received after spring broadcast applications on 13-May-2012 until planting on 1-June-2012. This precipitation and cooler than normal temperatures delayed planting, and probably didn't result in conditions suitable for ammonia volatilization losses from surface applications of urea, thus the use of Agrotain didn't seem to make much difference. *AB-28*

Large Urea Granules for Broadcast Application for No-till Cropping in Spring Wheat

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Project Cooperators: Dick Puurveen, Ross McKenzie, and Chengci Chen

The field work at this experiment progressed very well, all the fall N fertilizer broadcast applications (18-Oct-2010) and the spring broadcast applications (20-Mar-2011) were completed as planned. The crop was planted on 20-May-2011, after some delays because of cool wet weather. The crop year 2011 was an excellent growth year with 8.8 in. of precipitation after planting and warm dry weather in July and August to ripen the spring wheat crop sufficiently so that harvest was done on 8-Sept-2011, close to an average harvest date for the area. The challenge about having a moist warm growing season is that even though the site was initially rated as deficient in N, there was probably above average mineralization of N soil organic matter by the soil microbial population. The above average N mineralization caused the check or zero N treatment to yield well, 68 bu/A, compared to the N fertilizer treatments all applied at 63 lb N/A, that ranged from 66 to 74 bu/A. Yields in this area are more commonly around 40 to 45 bu/A. Measurements of grain height at harvest showed that the majority, 16 out of 18, of the 18 fertilizer treatments had significantly taller wheat (at 90% confidence) than the check treatment. That being 30 in. height for the check treatment compared to a range from 31 to 34 in. height for the fertilizer N treatments. Variability at the site was very low for both yield and crop height, i.e. 7% and 3% coefficients of variation (CV) respectively. All fertilizer treatments yielded well with no significant differences between granule size (1/8 in. compared to 1/2 in.), time of application (fall or spring), and with or without urease and nitrification inhibitors. It is hoped that with a more normal precipitation year in 2012 that there will be a greater response to fertilizer N compared to the check treatment, and that differences between N fertilizer treatments will be observed. It is planned to conduct the experiments for two more years on a field near the location. *AB-29*

British Columbia

Evaluation of Phosphate and Nitrogen Fertilizers Treated with Polymer Additives to Increase Efficiency

Project Leader: Claire Langlois, BC Grain Producers Association, Dawson Creek, BC. E-mail: bcgpa-r@pris.ca

Project Cooperators: Dick Puurveen, Guy Lafond, and Brian Hellegards

Fortunately, this set of research experiments was conducted under favorable weather conditions in 2011. During the previous 3 years (2008 to 2010) this area experienced severe drought, but growing season moisture was received close to the normal 11.6 in., in contrast to 2010 when only 7 in. was received. Barley yields were high with average yields over 100 bu/A.

In the P experiment there was no significant response to applied P with the control or zero-P treatment yielding similar to all rates of P, both 15 and 30 lbs P_2O_5/A. The zero-P treatment yielded 100 bu/A, and all the P treatments yielded between 94 to 114 bu/A, with a Least Significant Difference (LSD) of 20 bu at a 90% level of confidence. Perhaps since the area came out of a severe drought after 3 years, there was enough available P from increased microbial activity that there was no response to applied P. Since there was no response to P, there was no differences observed between form of P fertilizer (i.e. ammonium polyphosphate, or monoammonium phosphate), rate of P_2O_5 (0, 15 or 30 P_2O_5/A), and whether or not the Avail® polymer was added or not.

There was an even higher yield measured in the N experiments. The check or zero N treatments averaged 120 bu/A, while all the N fertilized treatments, both 54 or 108 lb N/A averaged around 150 bu/A. There was about a 30 bu/A response to added N whether 54 or 108 lb N/A. In comparing the three forms of N, the overall average yields did not show any significant differences. Regular untreated urea averaged 150 bu/A, the Super Urea® 150 bu/A, and the Nutrisphere®-N treated urea yield was 151 bu/A, with an LSD of 7 bu/A at 90% confidence. The data from the 4 years of the study at this site will be grouped and final data analysis done to compare regular P and N fertilizers to those treated with polymer additives, and urease, and nitrification inhibitors. This analysis will be described in the final project report. *BC-17F*

Manitoba

Impact of Long-Term Application of Phosphate Fertilizer on Cadmium Accumulation in Crops

Project Leader: Cynthia Grant, Agriculture & Agri-Food Canada, Brandon, MB. E-mail: cgrant@agr.gc.ca

Project Cooperators: Wole Akinremi (University of Manitoba), Don Flaten (University of Manitoba), Xiying Hao (AAFC Lethbridge), Ross McKenzie (Alberta Agriculture), Dick Purveen (University of Alberta), and Sukhdev Malhi (AAFC Melfort).

Cadmium (Cd) can accumulate in soils from long-term application of P fertilizer, but the availability of the Cd added in P fertilizers will be affected by soil characteristics. Field studies were established in 2002 at seven sites across the Canadian prairies to evaluate the impact of repeated applications of 0, 20, 40, and 80 kg P/ha of monoammonium phosphate (MAP) fertilizer containing 0.38, 70, or 210 mg/kg of Cd. The sites were planted each year following a durum wheat-flax cropping sequence. Fertilizer was applied each year until 2009. Grain concentration of Cd was measured each year in each treatment and the soil concentration of Cd, P and other elements was measured in the 0 to 7.5 and 7.5 to 15 cm soil depths in the control and at the highest P application rates. In 2010 and 2011, crops were seeded with no addition of P fertilizer to evaluate the residual effect of the long-term application of P and Cd on grain Cd and on the DTPA-extractable Cd and Olsen, Mehlich-3 and water–extractable P concentration in the 0 to 7.5, and 7.5 to 15 cm depth of each treatment. Chemical and statistical analysis of the 2010 and 2011 samples is continuing.

Based on the data analyzed to date, extractable P was strongly related to the amount of P added to the soil with the rate of increase being inversely related to soil CEC, pH, Fe, and Ca. DTPA extractable soil Cd in the surface 7.5 cm depth increased with application of MAP containing moderate or high concentrations of Cd, but concentration in the 7.5 to 15 cm depth only increased with the high-Cd MAP. Cadmium concentration in both durum wheat and flax seed increased with increasing input of Cd, but the magnitude of the effect varied with soil characteristics and was not consistently related to DTPA-extractable soil Cd. Plant availability of the Cd added in P fertilizer was higher on coarse-textured or acidic soil than on fine-textured or higher pH soils. As the effect of MAP applications on extractable P and Cd in the soil and on grain Cd concentration is affected by soil characteristics, it is important to consider soil characteristics when assessing environmental and health risks associated with P and Cd accumulation in soils. *MB-24*

Montana

A Micrometeorological Study to Quantify Ammonia Volatilization Losses from Surface-Applied Urea in the Semiarid Northern Great Plains

Project Leader: Richard Engel, Montana State University Land Resources and Environmental Sciences, Bozeman, MT. E-mail: rengel@montana.edu

Montana grain growers annually seed over 5 million acres of wheat, primarily winter wheat. Nitrogen is the primary nutrient that limits wheat production on this land. Hence N fertilization is essential for sustaining yields as well as ensuring production of high protein quality grain. To meet this challenge Montana wheat growers apply N fertilizer to their fields. Most frequently this is achieved through broadcast applications of

urea-N (46-0-0) to the soil surface with applications occurring between October and early May. Surface urea applications are susceptible to ammonia (NH_3) volatilization losses if not incorporated with tillage or by rainfall. A number of environmental and soil related factors interact together to affect this process and define the magnitude of loss. Research has continued on this project for the fourth year.

There have been sufficient sites where NH_3 losses were measured (approx. 20), with different weather patterns experienced, that it is now possible to better understand what weather and soil conditions result in low, moderate, and higher relative losses of NH_3. The loss amounts and associated weather patterns can be separated into three categories: low (when applied urea loss is <10%), moderate (when applied urea loss varies between 10 and 20%) and high (when applied urea loss is >20%). Associated soil and weather patterns for these categories include urea applied to dry soil surface then large precipitation events (>0.7 in.) following fertilization for the low category, urea applied to dry soil surface followed by light scattered precipitation events (<0.3 in.) for the moderate category, and urea applied to wet or damp soil surfaces followed by slow drying without precipitation, daily soil temperatures cold (-2 to 3˚C) for the high category.

At all of the research sites besides a control or zero N treatment, there has been an application of NBPT urease inhibitor (Agrotain® at 0.01% by weight) to urea for comparison. Generally use of NBPT has been shown to reduce NH_3 losses by around 50%. Additional laboratory experiments are being conducted to better understand the effect of soil pH on the length of effectiveness of the NBPT. This is being done because of observations made of increased length of effect of NBPT on alkaline soils compared to acidic soils. Laboratory research on this will continue over the next year. *MT-17*

Nitrogen Fertilization Methods for No-till Cropping of Winter Wheat in Central Montana

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Project Cooperators: Audrey Bamber, Dick Puurveen, and Ross McKenzie

The most common method of applying N fertilizer to winter wheat crops in central Montana, is to broadcast urea or dribble apply liquid urea ammonium nitrate in the late fall, or early spring. With shallow soil profiles in central Montana, the soils do not hold much precipitation over winter. When precipitation exceeds the soil water holding capacity, the excess water carries N out of the soil profile, causing ground water contamination.

A study was started in the fall of 2010 to compare other possible methods of applying N fertilizer to winter wheat crops, that may reduce the risk of leaching or denitrification losses of applied N fertilizer. Other possible methods include side-banding urea during the planting operation of wheat in mid to late September, placement of ESN® or controlled-release polymer coated urea in the seed-row of wheat at planting, or application of urea treated with urease and nitrification inhibitors in the mid-fall or early spring. In this experiment the winter wheat was planted in mid-September 2010, the two at-planting treatments described above were applied at this time. The fall broadcast treatments were applied on October 5, 2011, and the spring broadcast treatments on March 24, 2012. Treatments included: urea broadcast in mid fall (Urea BF), urea broadcast in early spring (Urea BS), Super Urea® broadcast in mid fall (SUreaBF), Super Urea broadcast in early spring (SUBS), ESN applied in the seed-row at planting in the fall (ESNWSF), regular urea applied in the seed-row at planting in the fall (UreaWSF), and check (no N applied).

Winter wheat grain yield was significantly affected by N source, application timing, and application method. Generally, spring application had greater yields than fall application. In this initial study Super U (containing both a urease and nitrification inhibitor) did not result in a greater yield compared to regular urea whether applied in the fall or spring. The mid-row banded application did not result in a greater yield than the broadcast application in the fall. This study will be continued for two more growing seasons. *MT-18*

North Dakota

Nitrogen Recalibration for Corn in North Dakota

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This is the second year of the project designed to allow the research-based re-evaluation of the corn N recommendations in North Dakota. A total of 22 sites were planned in 2011. With the sites from 2010, there have been a total of 36 sites that can be evaluated. In addition, sensor readings using both a Greenseeker® (N-Tech) sensor and a Holland Scientific Crop Circle sensor were used when the corn was about 6 leaf and again about 2 weeks later over the top, and at the later season also below canopy height. These sensor readings were taken to try to develop a predictive measurement to guide growers in the need for added N at side-dress time. The site yield and N-rate evaluations were evaluated as a whole and partitioned based on regional and soil considerations.

The response of corn to N rate from the total of the two years was quite variable ($R^2 = 0.19$). The no-till sites, a total of five in the 2 years, responded differently than conventional sites, and the 50 lb N/A long-term credit used in the spring wheat and durum recommendations also appears to be justified for corn. High clay sites required far more N for similar yields as the remaining eastern North Dakota sites. Based on a comparison of similar yields from the rest of eastern North Dakota, clay sites lost about 80 lb N/A in 2010 due probably to denitrification and more than 120 lb N/A in 2011. The well-tiled clay sites were less affected by N loss and responses to N near those of medium-textured soil sites in the east. Considering the amount of N lost in high clay soils in 2010 and 2011, and probably by growers in many springs, there is ample cause to begin recommending a planned side-dress N application in high clay soils. It is planned to conduct field sites for two more years, 2012 and 2013, and then summarize the experimental results and release updated N recommendations for the various regions in North Dakota. *ND-16*

Saskatchewan

Evaluation of Urea Nitrogen Fertilizer Treated with Nutrisphere® Polymer Additive to Increase Fertilizer Efficiency

Project Leader: Guy Lafond, Agriculture and Agri-Food Canada Indian Head Research Farm, Indian Head, SK.
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Project Cooperators: Claire Langlois, Dick Puurveen, and Brian Hellegards

This project, at the Indian Head Research Farm near Indian Head, Saskatchewan, consists of three experiments comparing regular granular urea, urea treated with Nutrisphere-N® (a polymer coating), and Super Urea® (including both urease and nitrification inhibitors) at 45, 90, and 135 kg N/ha. The experiments were conducted on spring wheat, barley, and canola. The study was initiated in April 2008, and repeated in 2009, 2010, and 2011. In 2011, growing conditions were cool and more moist than normal, early in the growing season, and drier and warmer than normal in the last half of the growing season.

A significant response to N was observed for all three crops. There was a slight overall yield benefit to the slow release N products observed with canola, but not for wheat or barley. It is thought that the soil conditions susceptible for denitrification losses were met at Indian Head from late May through June which could have increased the potential for a benefit to the side-banded Super-U and NSN, but at least for the barley, yields were limited more by the excess spring moisture than by N. Both the wheat and the canola ended up yielding well and the response to N for both crops was quite linear up to 134 kg N/ha. The conditions suitable for denitrification losses are not experienced very often in this area of Saskatchewan, but it does demonstrate the potential benefits of these enhanced urea products when the potential for N loss is high. *SK-40F* ❖

Americas and Oceania Group

North America

Western Region: Dr. Robert Mikkelsen

Arizona

Improving Nitrogen Fertilizer Management in Surface-Irrigated Cotton

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Project Cooperator: Pedro Andrade-Sanchez, Doug Hunsaker, and Eduardo Bautista

The first year of this project was devoted to comparing N sources for furrow-irrigated cotton, develop a tool for predicting N fertilizer response using canopy reflectance-based N management in surface-irrigated cotton, and constructing a N balance for surface-irrigated cotton (quantify total N uptake, recovery N use efficiency, NO_3 leaching, and denitrification losses).

High pre-plant soil NO_3 precluded yield response to N this year. We discovered that the field arrangement does not allow uniform irrigation of three replicates of 8 row plot-treatments with the 520 foot runs at 3 to 3.5 inches. We were not able to mix 5% ammonium sulfate solutions so that fertigation treatment was not applied. The in-season transect soil profile NH_4^+ and NO_3^- data did not show the effect of knifed or fertigated N fertilizer against the high pre-plant soil NO_3^-.

We did collect valuable sets of canopy reflectance/four vegetative indices. The total N uptake data at first open boll resulted in valuable internal N use efficiency data (67 lb N/bale). The nitrous oxide emission data was high quality data, some of the first of its kind. Nitrous oxide emissions were barely detectable in all N treatments during the 56-day measurement period following fertilization and fertigation, with the exception of the fertigation treatment. That treatment lost 0.9% of fertigated N as N_2O, which is in the range of N_2O losses measured from drip-irrigated cotton in Texas.

Amber NDVI (amber being 590 nm) using 820 nm had less up or down noise than the other indices. Calculating NDVI with a red edge (i.e. 730 nm) of NIR reportedly has the advantage of not saturating at high leaf area levels. Amber NDVI using 820 nm had the highest correlation among the indices with in-season biomass and N uptake. *AZ-08*

California

Assessment of Alfalfa Yield Monitoring Technology to Improve Nutrient Use Efficiency

Project Leader: Andre Biscaro, University of California, Lancaster, CA. E-mail: asbiscaro@ucdavis.edu

Project Cooperator: Steve Orloff

Yield mapping has been beneficial by demonstrating the degree of yield variability in areas much smaller than whole fields. Although growers recognize this variability, it is difficult to measure and map without a yield monitor. Grain crops have led the way with yield monitoring technology, which is not widely used or is still under development for many other important crops. In other crops like alfalfa the technology has not even existed until recently. Using bale sampling and tissue testing and then noting the bale locations with a GPS, hay quality and crop nutrition status can be linked with yield data for specific locations in the field. Overall, we expect that the use of yield monitoring data can significantly increase fertilizer use efficiency by meeting specific crop needs, increase hay yield and quality, and reduce potential P and K losses to the environment.

In order to assess the accuracy of an experimental yield monitor, biomass samples were collected from three windrows and weighed during the fifth cutting of one alfalfa field, and compared with yield monitor values. Management zones were created based on the previous cutting yield maps, where high yielding and low yielding zones had been established. The comparison of biomass samples and yield monitor values consisted of comparing sections of the alfalfa windrow to the closest bale weight from the yield monitor.

Although the alfalfa yield monitor was simple to install and operate, a considerable amount of data was lost during the baling processes due to different reasons related to equipment malfunction. Of the three fields monitored, we were unable to collect whole field data for any of them for all the five cuttings during the 2011 growing season. This fact made it difficult to advance to the next step of the project: defining management zones and assess the yield monitor accuracy.

Overall, the yield maps created with the yield monitor were able to show clear yield differences in different parts of the fields, which were confirmed by the grower. However, the biomass weight comparison between the yield monitor and the tarp method showed an unacceptably large difference in dry yield (over 30%). Therefore, we expect to investigate the possible causes of the yield monitor's lack of accuracy during the 2012 growing season and attempt to meet the original objectives. *CA-30*

Relationship of Soil Potassium Fixation and Other Soil Properties to Fertilizer Potassium Rate Requirement

Project Leader: Stuart Pettygrove, University of California Department of Land, Air & Water Resources, Davis, CA.
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Project Cooperator: Randal Southard

Potassium is an essential element in plant nutrition, and a sufficient supply of K is required to maximize crop yield. Some minerals fix K by trapping it in their interlayer region. Vermiculite is commonly found in the silt and fine sand-sized fractions of soils formed from granitic parent materials. For our current research, we selected these K-fixing soils from Central California.

Measuring levels of plant-available K can be challenging, especially in soils with high K fixation potential. Several techniques have been developed, but there is no agreement on the best way to predict the effects of K fixation. The most common laboratory method for measuring plant available K is extraction with ammonium acetate (NH_4OAc). Extraction with sodium tetraphenylboron (NaTPB) correlates closely with K uptake by plants. A new test (Kfix) was developed by Murashkina, which predicts K fixation potential.

To analyze the fate of added K, a potassium chloride (KCl) solution was added to air-dried soil at concentrations equal to the initial Kfix value. Moist soils were incubated for up to 16 days and then analyzed by the NH_4OAc and Kfix methods. The NaTPB method was not consistent for moist soils in this study. Subsamples were allowed to air-dry and extracted. Samples were subjected to four cycles of wetting and air drying after the initial application of K and analyzed after each drying cycle.

Even after adding K equal to the Kfix values for these soils, they continued to fix K, though at levels lower than for the untreated soils. The extracted K increased after K addition, but by amounts less than the K that had been added. Kfix was independent of the duration of incubation. Changes to the fixation potential of these soils after the addition of K all took place in the first 24 hours. For all soils, Kfix values for moist samples were lower than for their dried counterparts. Additional cycles of wetting and air drying had no discernible effect on the extractable K. Any changes took place upon drying were not enhanced by repeating the wetting and drying process. Further development of this information will be useful in understanding the fate of fertilizer K applied to K-fixing soils, and in developing better fertilizer recommendations. *CA-31*

N_2O Emissions from the Application of Fertilizers: Source Partitioning

Project Leader: Johan Six, University of California Department of Plant Science, Davis, California.
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Project Cooperators: Charlotte Decock and Clifford Snyder

Nitrous oxide (N_2O, a potent greenhouse gas (GHG)) emission reduction protocols are being developed by different entities with different interests, several of which rely only on reductions in N rate to achieve reduced N_2O emissions. A project was initiated in late 2011 to perform a meta-analysis of the peer reviewed published science to determine the effects of all four R's (right source, rate, time, and place of application) on N_2O emissions in corn-soybean or continuous corn systems in North America, with a focus on the U.S.-states of Iowa and Illinois. More than 100 research papers have been assembled for potential inclusion of relevant parameters in the database; including presence and amount of irrigation, soil bulk density, water-filled pore space, and changes in soil organic carbon content or CO_2 emissions where available. The database will also include class variables for N timing (fall, spring, split, side-dress, etc.), placement (surface broadcast,

incorporated, banded, etc.) and N source (urea, anhydrous ammonia, ammonium nitrate, urea ammonium nitrate, etc.). Completion of the database is expected by Spring 2012, and actual meta-analyses will follow.

This work helps support the TFI-led USDA Conservation Innovation Grants (CIG) demonstration project which aims to demonstrate that Midwestern corn-soybean producers can be incentivized to adopt new fertilizer management practices that will reduce N_2O emissions, increase crop productivity and nutrient use efficiency through BMP implementation, while also generating revenue from the monetization of carbon-based GHG credits. *CA-32*

Western Nutrient Digest- A Regional Publication to Promote Nutrient Efficiency

Project Leader: Rob Mikkelsen, International Plant Nutrition Institute Western U.S. Region, Merced, CA. E-mail: rmikkelsen@ipni.net

The University of Idaho started a state-wide quarterly publication in 2008 to highlight their current research in plant nutrition and fertilizer management. University funding for this publication was eliminated due to budget cuts and distribution of the Nutrient Digest ceased. New funding from IPNI has allowed this valuable electronic publication to begin again and further to expand to include ten states in the Western U.S. region. The range of topics addressed in each issue and variety of crops discussed has significantly expanded to include items of interest throughout the region. Contributing authors are solicited to write on topics that are of current interest or that reports on important new research information. As the Digest continues to become better recognized in the Western U.S., it is anticipated that future funding will come from private industry to support the publication. Past copies of the newsletter are available at: http://www.extension.uidaho.edu/nutrient/newsletter.html. *CA-00D*

Idaho

Root Scans to Document Fertilizer Response

Project Leader: Jared Williams, Brigham Young University, Rexburg, ID. E-mail: williamsj@byu.edu

Project Cooperators: Kevin Anderson and Blake Willis

This rhizotron project to monitor root growth in soil was initiated with two objectives. The first was to develop educational tools with in situ demonstrations of root growth as influenced by nutrients. The second objective was to create still images and videos of root growth that could be posted on the internet. Root systems of growing plants are observed with a flat-bed scanner buried in the soil as part of a laboratory experience for a crop physiology class. The rhizotrons have also been used to conduct undergraduate research projects.

Student's involvement in the project has been important to its success. In the class, the students design independent research projects with various crops (alfalfa, wheat, barley, corn, soybeans, and potatoes), and fertilizer treatments (rate, placement, and nutrient source). Students have posted root images and videos on websites such as Facebook and YouTube. The rhizotron has been an excellent teaching tool and has facilitated students' understanding of root growth and fertilizer response. For example, one student used the rhizotrons to observe alfalfa nodulation as influenced by different fertilizers. The research was presented at the 2011 American Society of Agronomy meetings and helped him decide to pursue a graduate degree.

Funds from IPNI are used to purchase and maintain the equipment. Equipment requirements include a computer for image processing, 15 flat-bed scanners that are used to observe roots, and other items for building the rhizotron. As part of the project, two students have been employed to manage the project and produce videos and images. This project will produce educational tools that illustrate root growth and demonstrate techniques that can be adopted by other educators to illustrate root and nutrient interactions. *ID-11*

Documenting Phosphorus Efficiency for Potato Production

Project Leader: Bryan Hopkins, Brigham Young University, Provo, UT. E-mail: hopkins@byu.edu

Proper P nutrition is a key component for growing high quality and high yielding potatoes. There is a need to synthesize the existing scientific information and present it in a way that can be used for improved fertilizer management. A significant body of research has now been assembled to review P fertilization practices for potatoes. These diverse reports have been synthesized into the 4R concept to deliver P in the right source and at the right rate, time, and place. A PowerPoint presentation is currently under development that will be added to the on-line library of the IPNI Crop Nutrition Series and made available for a global audience. *ID-12*

Utah

Can Tart Cherry Yield and Fruit Quality be Increased with Improved Phosphorus and Potassium Management?

Project Leader: Grant Cardon, Utah State University Extension Soils, Logan, UT. E-mail: grant.cardon@usu.edu

Project Cooperators: Brent Black and Earl Seeley

Cherry farmers are rewarded for both high yields and excellent quality (such as fruit size, soluble solids, and acid content). Very little field research has been done on the nutritional requirements of tart cherries and their response to added fertilizer. Because trees have such large root systems and they have a large internal storage of nutrients, it often takes several years before either nutrient deficiencies or fertilizer-induced yield increases are observed. This multi-year study was designed to determine the source, rate and time of P and K application to maximize production of high quality tart cherries in Utah. Field research plots were established in 2010 on five commercial cherry orchards ranging in age from 15 to 20 years. Various rates, sources, and combinations of P and K were applied to the orchards at annual rates up to 2 lb of material per tree. Applications are made either once or twice per year.

Fruit yields exceeded 200 lb fruit/tree for many of the treatments in 2011. Since tart cherries are alternate bearing, this was a heavy fruit producing year, compared with 2010 when yields averaged only 100 lb/tree. In general, fruit yield responded positively to both P and K application, although K generally had the greatest positive effect. Splitting the applications into two annual doses did not have any yield benefit compared with a single annual application of P and K. There was some difference between the sites (with different soils and fertilization histories), but an overall positive response was measured to added P and K. In general, there was no fruit yield or quality benefits from the specialty P or K fertilizer products compared with more common fertilizer products. However, the use of potassium sulfate consistently increased the soluble solid content of the fruit. It is not clear if this is due to the K or the additional sulfur in this material.

Cherry leaf tissues are being sampled throughout the growing season to develop diagnostic criteria to allow growers to predict the need for additional nutrients. Leaf nutrient concentrations are being measured in the laboratory to correlate with fruit yield and fertilizer additions. This will allow us to provide guidance in the future to cherry farmers on when nutrients may be limiting and how much fertilizer is needed. *UT-07* ❖

Americas and Oceania Group

North America

Northcentral Region: Dr. Scott Murrell

Iowa

Variability in Soil Test Potassium and Crop Yield in Iowa

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We advanced at summarizing, for publication, a project to study the impact of genetic rootworm resistance on corn response to K. Work also continued on five long-term trials with corn-soybean rotations managed with and without tillage to understand soil-test K (STK) temporal variability and relationships among K rates, placement, STK, and grain yield. A summary was completed of 16 years for the no-till treatment, which included measuring removed K.

Potassium had inconsistent or small effects on grain K concentration (means of 0.32% for corn and 1.63% for soybean), but increased yield and K removal with STK less than 150 to 180 ppm. Yield was poorly correlated with grain K concentration, but was linearly correlated with removal. STK decreased 2.5 to 3.8 ppm per yr. STK and K removal were well correlated only over the long term. There was a large stratification of STK and non-exchangeable K, and non-exchangeable K partially explained STK variation across K rates and years.

Work was also completed for a third year of two trials that evaluated interactions among hybrid (rootworm susceptible or resistant) and N-K fertilization in corn. Analysis completed for one site showed a positive N-K-hybrid interaction (higher yield and response to N with adequate K for the resistant hybrid). Results of tissue tests for grain and leaves are being studied. Finally, progress was made on the study of K recycling with corn residue at seven trials. We observed significant K loss from standing plants or residue from physiological maturity until the following spring. About 70% of the plant K was lost by late March, and precipitation increased K loss. *IA-09F*

Global Maize Project in the United States: Ames, Iowa

Project Leader: Roger Elmore, Iowa State University Agronomy Department Ames, IA. E-mail: relmore@iastate.edu

Project Cooperator: John Sawyer

The objective of this study is to determine whether or not an ecological intensification approach can increase yields more quickly over time than current farmer practice. The study design is a split plot. The main plot is management system: 1) farmer practice (FP), and 2) ecological intensification (EI). The split plot is: 1) N application according to the management system, and 2) no N. The treatments are in a randomized complete block, with four replications.

In 2011, there were no soybean grain yield differences between the systems (58.8 and 60.8 bu/A for FP and EI, respectively). For corn grain yield, the N application was significant between without and with N (138 and 221 bu/A for without and with N, respectively). There was no effect of management system nor was there an interaction between management system and N application. Therefore, the site was highly N responsive in both systems, but systems or differences in N source and application rate had no effect on corn yield (FP with N was 220 bu/A and EI with N was 222 bu/A). *IPNI-26*

Indiana

Comparative Nutrient Use Efficiency by Candidate Biofuel Crops

Project Leader: Jeffrey Volenec, Purdue University Department of Agronomy, Lafayette, IN.
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Project Cooperators: Sylvie Brouder, Keith Johnson, and Brad Joern

Maximizing biomass yield while minimizing nutrient input represents a new challenge for bioenergy cropping systems. Our objective in this study initiated in 2007 was to determine if nutrient use by perennial and annual bioenergy crops was fundamentally different from well-characterized cropping systems. Using meta-analysis and field experimentation, we studied the relationships between N, P, and K uptake, biomass yield, and composition of sorghum, Miscanthus, and switchgrass. Maize was included as a control.

Meta-analyses revealed that nutrient uptake scaled with biomass production across species. Nutrient losses to the environment occurred when senescent biomass was harvested in winter. Miscanthus and switchgrass biomass yields often were not increased with N, P, and K fertilization. High yields of switchgrass were possible with low tissue K concentrations that favor pyrolytic conversion processes. Under low N, yield of sorghum lines exceeded that of maize. Photoperiod-sensitive and sweet sorghum lines produced nearly twice the dry matter of maize at 67 kg N/ha. System differences in nutrient responses should be exploited when deploying candidate biomass species onto marginal soils. *IN-25F* ❖

Americas and Oceania Group

North America

Southeast Region: Dr. Steve Phillips

Alabama

Evaluation of Fertilizer Application Uniformity and Nutrient Distribution

Project Leader: John Fulton, Auburn University Biosystems Engineering, Auburn, AL. E-mail: fultonjp@auburn.edu

Project Cooperators: Charles Wood and Greg Pate

Blended fertilizers are commonly applied to crop and pasture land using spinner-disc spreaders. However, the nature of blended fertilizers can make it difficult to spread uniformly due to varying physical properties of the different granules, which can lead to segregation during application. Further, variable-rate application of blended fertilizer could pose challenges in terms of accuracy and uniformity to meet target prescription rates. Therefore, a study was conducted with the primary objective of evaluating the potential of fertilizer segregation during application with a spinner-disc spreader. A series of standard pan and field tests were performed to evaluate mass and nutrient distribution for a blended fertilizer product (17-17-17). Spreader calibration was conducted prior to data collection according to manufacturer specifications. After calibration, replicated standard pan testing was conducted to measure both distribution based on mass and nutrient (N, P_2O_5 and K_2O) concentration across the spread width. Field tests consisted of generating fertilizer prescription maps followed by a variable-rate application using 17-17-17. Collection pans were randomly placed across the field and fertilizer collected in each pan was weighed to determine the actual rate applied and analyzed for nutrient concentration. Field data, prescription, and as-applied maps were used to evaluate performance and product segregation.

Results indicated that P and K concentrations (CV 25% and 26%, respectively) varied significantly across the swath and in the field indicating the occurrence of fertilizer segregation. Nitrogen concentration remained uniform across the swath during both pan tests (CV=4%) and during field application (CV<8.5%). Particle size difference between the individual fertilizer constituents was the primary reason for segregation. The segregation of fertilizer particles resulted in under-application of P, but under- and over-application of K during field application. Of note, this study represents results for one spreader setup and a single blended product and may not reflect possible performance for a different setup, spreader, and other blended products. A more detailed study is planned for 2012 to gain insight into understanding blended formula segregation applied with modern spinner spreaders. *AL-21*

Arkansas

Biomass and Macronutrient Accumulation and Losses in Switchgrass During and After the Growing Season

Project Leader: Charles West, University of Arkansas Crop, Soil and Environmental Sciences, Fayetteville, AR. E-mail: cwest@uark.edu

Field studies were conducted for the third year on switchgrass yield response to N fertilizer in northwest Arkansas. Another study evaluating N, P, and K fertilizer response was established in eastern Arkansas in 2011 and switchgrass variety trials were conducted in 2010 and 2011. For the N, P, and K fertilizer trials, average forage yield was 7 ton/A. The fertilizer nutrients were tested in physically separate trials, which were adjacent to each other. In the N rate trial, N concentration increased, P concentrations were unaffected, and K concentrations declined with increments of N fertilizer. In the P trial, no elemental concentrations were affected by P fertilizer rates. In the K trial, there was a slight, nonsignificant trend for an increase in K concentration with K fertilizer increments, whereas N and P were unaffected. The N rate study in 2011 showed a significant increase in biomass yield with increments of fertilizer applied as urea in one application

in early May. The trend in response was linear from 0 to 90 lb N/A, then leveled off at the highest increment. This was similar response to that found in 2010. Yields were lower in 2011 than in 2010 because of record high summer temperatures and a prolonged drought. Concentrations and removal rates of N, P, and K are still being analyzed.

The variety trials compare advanced breeding lines 'Cimarron', 'C75', and 'C77' with the standard, commercially available cultivar, 'Alamo'. All plots received 60 lb N/A in late April each year. At the beginning of 2011, the plot area was found to have low soil test values for P and K. Therefore, 60 and 115 lb/A of P_2O_5 and K_2O, respectively, were applied to the plot area. Cimarron, a new release, exhibited greater biomass yield than Alamo. New, high-yielding cultivars of switchgrass would be expected to remove more N, P, and K from the field than Alamo. The added P and K fertilizer probably explains most of the increase in biomass yield in 2011 compared to 2010; however, somewhat more favorable rainfall in 2011 may explain some of the increase. Although not designed as a fertilizer response study, the results suggest that switchgrass does respond to P or K, with K being the more likely limiting nutrient, as indicated by the increased K tissue concentrations in the K fertilizer trial described above. *AR-33*

Florida

Bahiagrass Production and Nitrogen Leaching from Various Nitrogen Fertilizer Sources

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Bahiagrass covers nearly 5 million acres in Florida and is the most widely used improved grass in the state. This grass requires relatively moderate amounts of N for optimum production and can efficiently respond to inorganic fertilizer application. Nitrogen fertilizer can increase both yield and nutritive value of bahiagrass pastures, particularly in low fertility Coastal Plain soils where N is often the most limiting nutrient for forage production. Although N is an important agronomic input for productive bahiagrass pastures, increasing input costs and environmental problems associated with improper fertilization management have prompted the need to re-examine optimum rates and efficient sources to supply pastures with N. This experiment was designed to examine the effectiveness of various N sources on bahiagrass dry matter yield, nutritive value, and N leaching potential. Nitrogen was applied at 0, 50, and 100 lb/A/yr as ammonium nitrate (AN), ammonium sulfate (AS), urea, and ammonium sulfate nitrate (ASN) on a Basinger fine sand (siliceous, hyperthermic Spodic Psammaquents). The study was conducted at the Range Cattle Research and Education Center in Ona, FL during May to November, 2011.

Because of lack of rainfall in 2011, bahiagrass yields were significantly reduced as compared to previous years. Nitrogen sources increased cumulative bahiagrass dry matter yield by approximately 65% compared to control plots (no N applied). Bahiagrass yields responded linearly as N rates increased from 0 to 100 lb/A. Bahiagrass crude protein concentration was not significantly affected by N source. There were no significant differences in bahiagrass crude protein concentrations between the control plots (CP = 8.8%) and the treatments receiving 50 lb N/A (CP = 9.8%). However, application of 100 lb N/A resulted in higher CP concentrations (CP = 10.7%). Soil extractable inorganic N concentrations and soil pH at the 0 to 6 and 6 to 12-in depth were not affected by N fertilizer application. *FL-29F*

Nitrogen Rate Study for Potato Production in Northeast Florida

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With approximately 25,000 acres of winter and spring potatoes, Florida is an integral part of the supply chain for freshly harvested potatoes in the United States. Fertilizer BMPs are being developed to increase N-use efficiency for potato production and to reduce N-leaching. This ongoing study aims to determine optimal N-rates for commercial potato production. This study was performed with grower collaboration in six seepage-irrigated locations throughout northeast Florida, with three locations growing potato variety 'Atlantic,' and three growing 'FL 1867.' Nitrogen fertilizer rates ranged from 100 to 300 lb N/A as ammonium nitrate. All plots received 50 lb N/A of N at fumigation; N was then sidedressed twice with the plots receiving 0, 50, 100, or 150 lb N/A at emergence then 50 or 100 lb N/A at the 6 to 8-in growth stage. Total and marketable yield, specific gravity, plant dry weights, and N levels in the plants (tubers, leaves, and stems) were evaluated. Soil N levels were recorded throughout the season. Nitrogen content in the soil and N uptake into the plant were monitored throughout the season and potato yields were compared among treatments.

No difference in potato yields was observed among N rate treatments for Atlantic at any location. The Atlantic variety accumulated about 90 to 140 lb of N/A in the tissues (leaves, stem, and tubers). Atlantic total yield ranged between 200 and 290 cwt/A and N fertilizer rates above 230 lb N/A did not increase total yields. FL1867 was more responsive to N fertilization and highest yields were obtained when 100 to 150 lb N/A was applied at emergence in two of the three locations. For FL1867, total yields ranged from 350 to 395 cwt/A. For both varieties, the N accumulated by potato plants ranged from 130 to 190 lb N/A. The residual soil nitrate after harvest tended to increase according to N fertilizer rate. N fertilizer rates above 200 lb N/A left 60 to 120 lb N/A in the soil following harvest. The preplant N application did not increase soil N availability at plant emergence. Reduced soil N content coincided with heavy rainfall events. More research is needed to confirm these initial results. *FL-30*

Louisiana

Validation of an On-Site, Active Sensor-Based Midseason Nitrogen Decision Tool for Rice Production in the Mid-South

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Nitrogen is the most limiting and expensive plant nutrient in rice production. A need-based application of N fertilizer plays an important role in developing a more profitable and environmentally-sound rice production system in the Mid-South. Three years of optical sensor and rice yield data were collected and used to establish the working algorithm that runs a sensor-based N decision tool (SBN tool) that was used for determination of topdress N application rates for rice in 2011. Validation studies for the SBN tool were conducted at three sites in Louisiana and Mississippi using three rice varieties (CL152, CL162, and CL261). Different rates of N fertilizer applied either one time at preflood or split between preflood and midseason were arranged in a randomized complete block design with four replications. Two additional treatments, 75 and 105 lb N/A preflood N followed by a topdress N rate based on the SBN tool recommendation, were also included.

All sites were responsive to N fertilization except Rayville in Louisiana. Highest grain yield response was obtained from rice grown in Crowley (107% increase in grain yield). There were no significant differences in yield, N uptake, N use efficiency, and net return between plots which received SBN N rate recommendations and predetermined split N rates (75-45 or 105-45 lb N/A). However, topdress rate recommendations using the SBN decision tool ranged between 32 to 45 lb N/A and 21 to 28 lb N/A for Louisiana and Mississippi sites, respectively. Results showed that the SBN decision tool performed better than predetermined N rates using NUE and net return to N as performance indicators. Future work will include attempts to refine the working algorithm by considering the use of a single yield potential predictive equation for both Louisiana and Mississippi, and economic parameters (cost of rough rice and N fertilizer). *LA-24*

Missouri

Survey of Weed Nutrient Removal Potential in Missouri Soybean

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With the increasing adoption of glyphosate-resistant crops, concern for the timeliness of herbicide applications has declined and in many cases herbicide applications are made to large weeds that have already resulted in yield loss. With this in mind, a survey was conducted in 2011 to monitor 32 soybean fields in Missouri. The objectives of this survey were: 1) to determine the most common weeds encountered in soybean fields in Missouri, 2) to determine the average size and density of weeds present at the time of the post-emergence herbicide application, and 3) to determine the impact of typical weed infestation levels on nutrient removal. Observations were made once every two weeks from soybean planting through canopy closure in each of the survey locations. Just prior to the time of the post-emergence (POST) herbicide applications, sub-samples of weeds present at each location were harvested and analyzed for nutrient content.

At the time of the first POST herbicide application, all broadleaf weeds other than waterhemp were present at an average density of 1 plant/ft^2. The average height of broadleaf weeds other than waterhemp and all grass weeds present at the time of the first POST herbicide application were 7.5 to 10.5-in, respectively. Waterhemp was encountered at an average density of 2 plants/ft^2 and average height of 8.5-in at the time of the first POST herbicide application. Estimated soybean yield losses based on the weed densities and height of weed present ranged from 0 to 8 bu/A, with an average yield loss of 2.5 bu/A occurring across the 32 surveyed locations. Based on the weed densities present in the survey locations, the average amount of N, P, and K weed removal

in soybean fields in Missouri was 3.2, 0.4, and 3.7 lb/A, respectively. The weed infestations encountered also resulted in an average removal of 0.7 lb of Mg, 2 lb of Ca, and 0.3 lb S per acre. To date, these first-year results indicate that yield loss is likely occurring in the majority of soybean production fields in Missouri as a consequence of waiting too long to control broadleaf and grass weed species, and that at least some portion of this yield loss can be attributed to weed nutrient removal. *MO-34*

North Carolina

Soil Fertility Management for High Population, Narrow Row Corn Production

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The objectives of this research were to determine the optimum N timing and rate in high population, narrow row corn production systems. A series of 11 N fertilizer response experiments were conducted on Tidewater, Coastal Plain, Piedmont, and Mountain (grain and silage) region sites in North Carolina during 2010 and 2011. Corn yield response and yield components (# rows per ear, # kernels per row, and kernel size) were compared among wide row (30- to 40-in) and narrow row (15-to 20-in) corn that was fertilized with N either all at planting, or with both starter fertilizer (limited to 5 gpa 11-37-0) and sidedress N (between V5 and V8 stage). The starter band application of 6 lb N/A was applied to all plots in all experiments to insure rapid early season growth, except for one site to which 50 lb N/A had been applied uniformly in a granular pre-plant broadcast blended fertilizer. These data document general principles of N-use efficiency associated with different corn row widths and N application timing.

On average, approximately 0.7 lb N/bu was required to achieve optimum corn yield levels at these sites. In most cases yields did not differ due to N timing or corn row width. Nevertheless, when significant differences were noted, sidedress N applications resulted in higher yields compared with applying all N at planting, and narrow row planting resulted in higher grain yield than wide row planting. Data also suggest that corn plants experience more N limitations during late season periods, since changes due to N rates were detected in later-determined ear yield components, rather than plant and ear density components. The average number of rows per ear increased by a relatively small amount, from 15.9 to 16.4; while relatively greater increases were observed in row length, from 27 to 32 seeds per row, and seed weight, from 222 to 252 mg per seed. This could direct future management research into methods to ensure later season N sufficiency. *NC-21*

Kentucky

Evaluation of Sidedress Nitrogen Sources in Dark Tobacco

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Research was conducted in 2011 to evaluate the effect of several sidedress N sources on crop vigor, yield, and quality grade index of dark fire-cured tobacco. The site had a soil test P index of 62 (high), soil test K index of 216 (medium), and pH 6.2. One ton/A agricultural lime was applied and disk incorporated in early spring and 150 lb N/A (urea/DAP), 80 lb P_2O_5/A (DAP), and 180 lb K_2O/A (potassium sulfate) was broadcast and incorporated to the entire area on June 6, one week prior to transplanting 'PD7309LC'dark tobacco on June 14. Treatments were arranged in a randomized complete block design with 4 replications and individual plots were 4 rows by 40 ft long. Non-fertility practices followed standard production guidelines. Weather conditions during the 2011 season were wet prior to transplanting in April and May, with hot temperatures but adequate moisture during the growing season, and ample moisture during the curing season. Ambient rainfall was supplemented with drip irrigation in this trial. Sidedress N applications were made on July 22 at 150 lb N/A and immediately incorporated. Seven sidedress N source treatments were in the trial and included no sidedress (150 lb N/A pre-transplant only), Sulf-N 26 ammonium sulfate nitrate, 50:50 blend of Sulf-N ammonium sulfate and urea, ammonium nitrate, UAN-32 liquid, UCAN-17 liquid (CN-9 + UAN-28), and potassium nitrate. Crop vigor was evaluated in late August with the best crop vigor occurring from tobacco treated with potassium nitrate and lowest crop vigor in tobacco that received no sidedress N. Tobacco was manually stalk harvested in early October, housed in a traditional dark-fired barn, and fired four times with hardwood slabs/sawdust as is standard. Tobacco was taken down and stripped into 3 stalk positions (lug, second, leaf) in early December.

There were slight differences in the lug position yield, with lugs produced from tobacco treated with ammonium nitrate weighing slightly more than lugs produced from tobacco receiving no sidedress N or UCAN-17. Total dark fire-cured tobacco yield ranged from 3,441 to 3,642 lb/A with no statistical differences

among N treatments. There were differences in quality grade index between treatments, with the highest grade index occurring in tobacco receiving the 50:50 blend of Sulf-N ammonium sulfate and urea (56.8), and the lowest grade index occurring in tobacco receiving no sidedress N or UCAN-17 (30.6 to 31.2). *KY-10F*

Evaluation of Sidedress Nitrogen Sources in Burley Tobacco

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Various N fertilizer sources were evaluated for use in burley tobacco production during the summer of 2011. The materials tested included ammonium nitrate (34-0-0), calcium-ammonium nitrate (27-0-0), urea (46-0-0), and Sulf-N 26 ammonium sulfate nitrate (26-0-0-14S). An extremely wet spring at this location delayed planting until after the first of June. The field was prepared as is typical for burley tobacco production and a base rate of 50 lb N/A was applied in the form of urea. Burley tobacco (var. KT-209) was transplanted into the field on June 3.

At four weeks after transplanting, the sidedress N materials were applied at two rates (100 and 200 lb N/A). The field sustained moderate wind damage just prior to topping on August 11. The crop was harvested on September 12 and hung in curing barns. The wet start and wind damage tended to have a leveling effect across treatments. There was an effect of sidedress fertilizer to raise yield above the level of the 0-N sidedress check; however, all of the sidedress N materials performed similarly. *KY-11F*

Tennessee

Documenting Nutrient Deficiency and Accumulation Rate in Vegetables

Project Leader: Dharma Pitchay, Tennessee State University, Nashville, TN. E-mail: dpitchay@tnstate.edu.

A photo catalog of nutrient deficiency symptoms is being developed for common vegetable crops. The first phase of this research and education project is to induce mineral deficiency symptoms for various hydroponically grown plants in the greenhouse. Using purified nutrient solutions, plants were systematically deprived of each essential nutrient to observe the development of deficiency symptoms.

A complete set of deficiency photographs is now available for lettuce. Photographs for spinach deficiencies will shortly be available. Peppers and eggplant will be grown to produce deficiency symptoms and tissue samples throughout the growing season will be analyzed to determine nutrient accumulation rates. A project to determine a suitable solid phase media for this research was conducted so that root system deficiencies could be measured. Perlite contained sufficient trace concentrations of nutrients to mask some symptoms even after it was washed with acid.

A blueberry experiment was conducted to examine the impact of nitrate (NO_3) or ammonium (NH_4) nutrition on plant growth and root development. Blueberry shoot and root growth virtually ceased when nitrate was the sole source of N nutrition. A portion of the rootzone N must be in the NH_4 form for blueberries to grow. All the images of nutrient deficiencies will be available for educational use from IPNI as the project progresses. *TN-20* ❖

Americas and Oceania Group

North America

Southern and Central Great Plains Region: Dr. Mike Stewart

Kansas

Effect of Long-term Nitrogen, Phosphorus, and Potassium Fertilization of Irrigated Corn and Grain Sorghum

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This long-term western Kansas study was initiated in 1961 to evaluate responses of irrigated continuous corn and grain sorghum to N, P, and K fertilization. Furrow irrigation was used through 2000, and sprinkler irrigation since 2001. No yield benefit to corn from K fertilization was observed in the first 30 years and soil K levels remained high, thus the K treatment in the corn study was discontinued in 1992 and replaced with a higher P rate. Nitrogen treatments for corn and grain sorghum were 0, 40, 80, 120, 160, and 200 lb N/A. Phosphorus treatments for corn and grain sorghum were 0, 40, and 80 lb P_2O_5/A, and 0 and 40 lb P_2O_5/A, respectively. The K treatments for grain sorghum were 0 and 40 lb K_2O/A.

Corn yield was above average in 2011, with maximum yield at about 230 bu/A. Nitrogen applied alone increased corn yield by 87 bu/A, while N and P applied together increased yield up to 139 bu/A. This is similar to the past 10 years where N and P applied together increased irrigated corn yield by about 130 bu/A. Application of 120 lb N/A (with P) was sufficient to produce 95% of maximum yield in 2011. Nitrogen fertilizer alone increased sorghum yield by about 50 bu/A, while N plus P increased yield by up to 75 bu/A. Application of 40 lb N/A (with P) was sufficient to produce about 80% of maximum yield in 2011. Potassium fertilization had no effect on sorghum yield. This is one of the few continuous, long-term crop nutrition studies in the U.S., and support is planned to continue in 2012. *KS-23F*

Effect of Potassium, Chloride, and Nitrogen on Corn, Wheat, and Double-crop Sunflower Grown on Southeastern Kansas Claypan Soil

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Project Cooperators: Douglas J. Jardine and Kenneth W. Kelley

Corn acreage has been increasing in southeastern Kansas in recent years because of the introduction of short-season cultivars which enable producers to partially avoid mid-summer droughts that are often severe on the upland, claypan soils of the area. Also, producing a crop after wheat and in rotation with corn may provide producers additional revenue by growing three crops in two years. Recent interest and developments in oil-type sunflower provide an alternative to soybeans for growers to double-crop after wheat. The objective of this project is to determine the effect of N, K, and Cl^- fertilization on yield, yield components, and nutrient uptake of short-season corn, wheat, and double-crop sunflower grown in a 2-year rotation on a south eastern Kansas claypan soil.

Wheat yield, yield components, and leaf rust disease ratings were unaffected by K or Cl^- fertilization in 2011. Increasing N rate from 0 to 120 lb/A increased wheat yield, heads/A, and dry matter production at the soft dough stage, but slightly decreased seed weight. Average yield of double-crop sunflower following wheat in 2011 was low at 650 lb/A, likely because of unusually hot and dry conditions. Sunflower yields were unaffected by K, Cl^-, N, or their interactions, even though K and N fertilization increased the number of seeds per head. Potassium fertilization increased dry matter production at the R1 growth stage. Approximately 50% of the sunflower heads were affected by *Rhizopus* head rot, but disease incidence was not statistically affected

by fertilizer treatments. This study was initiated in 2010, and since crop response to fertilizer treatments has been marginal over the first cycle of this 2-year rotation, the work will not be continued. *KS-40*

Applied Fertility Management for Irrigated Soybean Production

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Irrigated soybean yields in North Central Kansas averaged about 53 bu/A over a recent 10-year period from 2000 to 2009. Although yields have trended upward, producers in the area are largely unsatisfied. Past research conducted at the Kansas State University North Central Kansas Experiment Field near Scandia has demonstrated that proper fertility management, including direct application of P and K, has the potential to significantly improve irrigated soybean yield. Despite the findings of this work soybean producers have been slow to adopt intensive fertility management programs. It has been speculated that adoption might be facilitated if these results were demonstrated on farmer fields outside the experiment station. The purpose of this research is to expand upon previous high-yield soybean work by including a field scale, farmer-cooperative component to increase awareness of irrigated soybean yield potential with proper fertility management.

This project will consist of a combination of small fertilizer response plots conducted at the KSU Irrigation Experiment Field and a field scale study on a producer's field. Small plot treatments will include a zero fertilizer control, and all combinations of 30 and 80 lb P_2O_5/A, and 80 and 120 lb K_2O/A. The effects of N and S will also be evaluated at the higher P and K rates. Field scale plots will be simpler, with one P (30 lb P_2O_5) and one K (80 lb K_2O) rate a combination of the two. This work was planned and cooperation established in late 2011, so results are not yet available. The first year of production will be 2012, and the project is expected to continue for three years. *KS-41*

Nebraska

Soil Test Phosphorus Level and Yield Potential

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Project Cooperator: Tim Shaver

This University of Nebraska-Lincoln project is designed to test whether maintaining high soil P availability is important to corn yield in enough years to justify the cost of building and maintaining high levels of soil P. The research, started in 2011, is being conducted at the Haskell Agricultural Laboratory (HAL), the Agricultural Research and Development Center (ARDC), and the West Central Research and Development Center (WCREC) in Nebraska. The sites have a history of conservation tillage. The HAL site is rainfed and the others are irrigated.

The effect of five P treatments on yield of irrigated continuous corn is being compared under no-till and disk till conditions at all sites. Initial soil Bray1-P level was less than 15 ppm at all sites. The P treatments are: 1) Bray1-P of <15 ppm - no P applied; 2) P applied according to the UNL recommendation; 3) Bray1-P raised and maintained at 25 ppm; 4) Bray1-P raised and maintained at 35 ppm; and 5) P applied based on removal. Phosphorus was applied before planting and tillage in the spring of 2011 assuming 12 lb P_2O_5 was needed to raise Bray-1 P 1 ppm. Zinc was applied to minimize the chance of P induced Zn deficiency. Trials have four replications.

Corn yield in 2011 at the ARDC was less than expected, probably because of high night temperatures in July. Also, there was no consistent response to applied P at ARDC, which may have been due to relatively high deep soil test P; however, early growth and early P uptake were increased with P application. Yield was consistently less with no P applied compared with other treatments at HAL and WCREC. This is the first of a five year study, so substantive conclusions cannot yet be made. Support will continue in 2012. *NE-14*

Texas

Nutrient Removal by Fruit and Vegetable Crops in Texas

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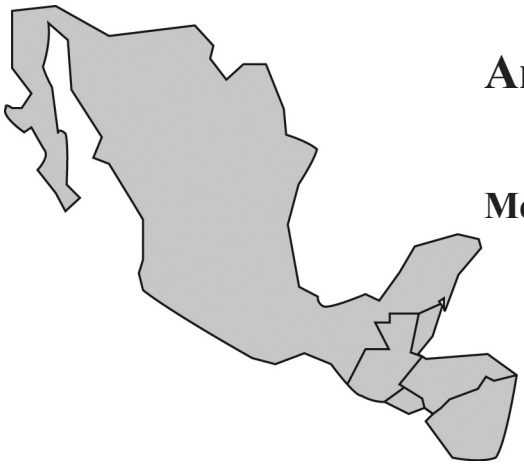
A balance between nutrient inputs and crop removal is required for effective long-term crop production. Although nutrient removal estimates are readily available for many field crops, such values for fruit and vegetable crops are rare. The objective of this project is to determine nutrient removal values for major fruits and vegetable crops grown in South Texas, and to use the information to help refine fertilizer recommendations for yield and quality.

During the spring growing season of 2011, nutrient removal amounts were estimated for muskmelons and onions from fields that were previously investigated in 2009. Removal rates by grapefruits from commercial orchards were also estimated (2011 only). Average melon yield in 2011 was 19.8 tons/A with nutrient removal averaging 92 lb N/A, 18 lb P/A, and 121 lb K/A. Sweet onion bulb yields in 2011 averaged 13.8 tons/A with average nutrient removal of 61, 19, 75 lb/A for N, P, and K, respectively. Grapefruit yields averaged 12.2 ton/A fresh fruit and nutrient removal averaged 29 lb N/A, 8 lb P/A, and 66 lbs K/A.

Continued sampling over multiple years and locations with varying weather conditions, soil types and yield scenarios will be needed to establish realistic nutrient removal values that can be used to develop improved fertilizer management guidelines. Support for this work will continue in 2012. *TX-55* ❖



Americas and Oceania Group

Mexico and Central America: Dr. Armando Tasistro

Global Maize Project in Mexico: Celaya, Guanajuato

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Project Cooperator: Benjamin Zamudio

The study started in 2009 in Celaya, State of Guanajuato, Mexico, at 1,830 meters above sea level. The treatment design included a combination of two management systems (plant populations) (Farmers' practice [FP] and a higher population [EI]) and three N fertilization regimes (0-N, 300 kg N/ha applied two out of three years, and 300 kg N/ha applied every year). In 2011, the six treatments were: 1) 120,192 seeds/ha, 0-N; 2) 120,192 seeds/ha, 300 kg N/ha (0 N in 2009; 300 kg N/ha in 2010); 3) 120,192 seeds/ha, 300 kg N/ha (300 kg N/ha applied both in 2009 and 2010); 4) 90,580 seeds/ha, 0-N; 5) 2) 90,580 seeds/ha, 300 kg N/ha (0-N in 2009; 300 kg N/ha in 2010); 6) 90,580 seeds/ha, 300 kg N/ha (300 kg N/ha applied both in 2009 and 2010). The first three treatments are considered as an intensification of the last three, which represent the traditional farmers' practice.

Yields responded to N, regardless of its application sequence. The application of 300 kg N/ha increased grain yields from an average of 1.9 t/ha to 10.9 t/ha, a reflection of significantly greater Harvest Index, more ears/ha, and larger ears with heavier kernels. Partial Factor Productivity and Agronomic Efficiency were 36 and 30 kg grain/kg N, respectively. No significant differences in grain yield could be detected between the intensive and traditional management options, although plant population at harvest differed significantly between them: 91,600 vs. 68,900 plants/ha, respectively. By harvest time, the plant population under both management systems had decreased by 24% on average, which is higher than normal, especially under experimental conditions. Most of that loss (15%) had taken place by the third week after crop planting. *IPNI-28*

Global Maize Project in Mexico: Toluca, México

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The study was started in 2009 in Toluca, State of México, at an altitude of 2,370 meters above sea level. The objective was to compare the effects of six combinations of plant populations and fertilizer applications. Half of the treatments—labeled as intensive management—included high plant populations and the application of a complete fertilizer formula (90 kg P_2O_5/ha, 90 kg K_2O/ha, 44 kg MgO/ha, 50 kg S/ha, and 3 kg Zn/ha). The other half of the treatments were similar to current farmers' practices with regards to plant population and fertilizer application (30 kg P_2O_5/ha and 30 kg K_2O/ha). Three N fertilizer application regimes were combined with the management systems just described: 0-N, 300 kg N/ha applied two out of three years, and 300 kg N/ha applied every year with the intensive management, and 0-N, 180 kg N/ha applied two out of three years, and 180 kg N/ha applied every year, with the farmers' management.

The 2011 season was very bad, with lack of rain at the beginning; followed by flooding, hail storms, and a devastating early frost in the first week of September. The yield levels were therefore lower than in the previous years. Yield under intensive management (3,594 kg/ha) was significantly higher than under traditional management (2,699 kg/ha). This result mirrored the differences in plant population at harvest: 80,208 and 62,691 plants/ha in the intensive and farmers' management treatments, respectively. Under intensive management, yields with N (3,906 kg/ha) were 31% higher than without N (2,971 kg/ha), whereas no significant effects from N could be detected under the traditional management. Partial Factor Productivity

was low under both management systems: 12 and 15 kg grain kg/N, for intensive and traditional, respectively. Likewise, Agronomic Efficiency was extremely low (3 kg grain/kg N for both management systems).
IPNI-29

Americas and Oceania Group

Brazil: Dr. Luís Ignácio Prochnow

Sustainable Production Systems under No-Till in the Cerrado of Brazil

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Continuous land cultivation with mono-cropping systems tends to promote soil degradation and increase the incidence of crop diseases, pests, and weeds, which in turn reduce crop yield potential. A long-term research project was initiated to look into various aspects of sustainable agricultural systems. The project focuses on crop rotation and other alternatives to generating long-term profitability. Part of this project is dedicated to the study of soil fertility management under these sustainable agriculture systems. Two experiments, one aimed at the production of fiber and the other at grain production, each containing seven different cropping systems, were initiated in 2008.

Results suggest that the production of dry matter of cover crops during the spring, before cotton, is sufficient for good soil protection and recycling of nutrients. Amounts of N, P, K, Ca, Mg, and S recycled by millet and Brachiaria grass were identical, while the amount of K recycled was higher for systems utilizing Brachiaria in the autumn and millet in the spring. The type of cover crop utilized during the spring did not influence cotton yield. The soil density was higher under no-tillage compared to annual soil tillage, but no fiber yield reduction occurred. For farming systems under no-tillage, soil density may be alleviated using Brachiaria grass for periods longer than 12 months, which may be an advantage for farming systems including pasture crops. The use of cover crops after soybean harvest is essential to sustain soil biological activity and nutrient cycling, and crotalaria showed higher levels of N cycled than Brachiaria and millet. Soil P levels were found to be lower in the farming systems with no use of cover crops after soybean, whereas the use of Brachiaria grass showed to increase P level in the soil.

Soybean yields were affected when it followed corn intercropped with Brachiaria. This could be related to immobilization of N in corn and Brachiaria residues. The intensification of the farming system with soybean and corn (second crop) in sequence resulted in higher amounts of nutrient export, which should be taken into consideration when planning fertilizer recommendations. If nutrient balance is not properly evaluated in intensive grain production farming systems it may endanger its sustainability. More conclusive results from this long-term project will be possible with time. *Brazil-53*

Sources and Rates of Phosphorus in a Cultivation System Integrating Crop and Pasture Production in the State of Parana

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The integration of crop and pasture production (ICP) within the same area, using no-tillage cultivation systems, is becoming popular in Brazil due to its agronomic advantages. Phosphorus is a key nutrient in these systems and soils in the state of Parana are generally low to medium in bioavailable P. The main purpose of this research is to evaluate the effects of P rates and sources (water-soluble and water-insoluble) on soil quality, plant mineral nutrition, forage, grain, and meat yields in an integrated crop-livestock system under no-till. The site has been under no-till for five years. Treatments included three sources of P [triple superphosphate (TSP), magnesium thermophosphate (MTP), and Arad reactive rock phosphate (RP)] and three rates of P (60, 120, and 180 kg total P_2O_5/ha), with all sources applied prior to seeding the winter crop. The trial also included a control, with no P applied, and three treatments supplying each source at 90 kg P_2O_5/ha applied prior to seeding the spring-summer crop.

Results so far indicate that it is possible to obtain high yields of maize and soybean (up to 12 t/ha and 5 t/ha, respectively) by anticipating the P application to the winter forage crop (black oats or ryegrass). Second, besides high grain yields, the anticipated P application leads to animal rate growth of up to 1 kg per day. Third, in the first 2 years, the TSP performed better as related to other P sources. Fourth, in the last year, crop response was higher with the MTP, and fifth, RP has performed as the least effective P source for this system. This project is expected to continue providing more insights until 2015. *Brazil-55*

Rates and Residual Effect of Potassium Fertilization in a Brazilian Soil

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Project Cooperators: Valter Casarin, IPNI Brazil Deputy Director, and Eros Francisco, MT Research Foundation.

Potassium is, most generally, the second nutrient in terms of plant demand (after N). This nutrient is responsible for several vital mechanisms for plant development and high yields (enzyme activation, translocation and stock of compounds, osmotic regulation, water maintenance, etc). Potassium fertilizers are a must for balanced plant nutrition in the acid soils of tropics, including Brazil. In many areas farmers are cutting back on fertilizer expenses, which could compromise good yields, profit and food safety in the future. The main objective of the study is to verify the effects of cutting back K fertilizer rates in some Brazilian soils. The study is also looking at other important factors which may affect the K fertilizer effectiveness in tropical soils (P, lime, phosphogypsum, time of application and locality effect) to evaluate 1) soil K status with time, (2) plant K status with time, and (3) grain yield.

Main results for the first crop season (soybean and corn second crop) indicated: (1) low response to K in soybean and no response in corn second crop, (2) no effect of lime, time of application, and location, and (3) higher K leaf contents with phosphogypsum application in soybean but with no effect on yield. These results indicate that we might be able to anticipate suppressing K application (after second crop year cycle and not after third as previously planned) in future. It will be interesting to find out the effect of liming and phosphogypsum application in deciding the K application suppression. This report summarizes data only for the first cropping year, though the project is planned for 6 years. *Brazil-56*

Soil Physical Properties, Dynamics of Nitrogen, Phosphorus, and Potassium, and Crop Yield as Influenced by Soil Compaction Under No-Till

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The practice of no-till is gaining popularity for several reasons, chief among them being adequate soil conservation in no-till areas. However, soil compaction has been noted as one of the main problems in areas under no-till cultivation for years. Not plowing the soil, plus the traffic of machines in these areas, leads to soil structure alterations resulting in poor soil physical quality and changes in the dynamics of N, P, and K. These conditions can all contribute to crop yield reductions. This project was planned to integrate chemical and physical evaluations of soils under no-till, foreseeing the need for future practical information to be given to farmers on how to manage soil compaction so as to obtain higher yields. The experiment is located in Ponta Grossa, Paraná, under a low fertility, acidic Oxisol high in clay, and under no-till for 20 years. The treatments consist of: 1) maintaining regular no-till system (RNT), and 2) no-till submitted to mechanical sub-soiling (SNT). The study is evaluating: 1) visual soil structure quality, 2) soil water characteristics and soil resistance, 3) soil hydraulic conductivity, 4) air permeability, 5) corn crop yield, and 6) leaf tissue analysis.

Results suggest some temporary improvement in soil physical quality in terms of soil structure and hydraulic conductivity in the SNT treatment as opposed to the RNT. Such temporary improvement, however, did not result in higher yields of corn and soybean. It is important to note that rainfall was adequate and well distributed during the two crop seasons. This may have diminished the possibility for differences between the two treatments, where advantages for the SNT would be expected. The higher concentration of P and K in the plants under the SNT, noticed in the first year, are most likely because both nutrients are transported to the root by diffusion. Thus, sub-soiling provided better conditions for plant root development, which in turn resulted in more P and K contact and absorption, and consequently, higher P and K concentrations in plants. New results for plant analysis are expected at the end of 2012 when this project completes. They might provide some interesting and new insights. *Brazil-57*

Global Maize Project in Brazil: Itiquira, Mato Grosso

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Cropping system intensification will be necessary to meet the future demand for corn (maize). Ecological Intensification (EI) seeks cereal production systems that satisfy future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project (GMP) was established to identify gaps in yield between current technology and improved technology aimed at achieving EI. The experiment was initiated in November 2009 at Itiquira, Mato Grosso in an Oxisol site that has been under cultivation for 20 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots involving three levels of N input plus a control. The types of cultivation being evaluated are: (1) farmer practice (FP) of soybean followed by corn; (2) FP + a forage crop (Brachiaria decumbens) in the winter; and 3) EI involving a 3-year complete crop rotation cycle of soybean, corn (second crop), forage, soybean, crotalaria, regular corn, and forage. The EI treatment occurs three times, alternating the initiation point of the crop rotation to permit the production of corn every summer. The levels of N input were 50, 100, and 150 kg N/ha for the first corn crop (summer crop) or 30, 60, and 90 kg N/ha for the second corn crop, plus a control with no N added in both cases.

The results to date indicate: (a) there were good responses to N in both corn crops, which positively influenced yields and total N uptake, (b) the addition of N positively impacted the dry-matter yield of the forage grass cultivated with corn, (c) soybean grain yield was higher when cultivated after corn second crop + forage than when cultivated only after corn, showing a positive effect of Brachiaria in the system, and (d) soybean crop responded to N previously applied to corn, showing that for high soybean yields N biological fixation may not be enough. This is a long-term project intended to influence current opinions on how to best manage cereal production in the region. *IPNI-18*

Global Maize Project in Brazil: Ponta Grossa, Paraná

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Cropping system intensification will be necessary to meet the future demands for corn. The proposed system of Ecological Intensification (EI) seeks cereal production systems that satisfy these future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project was established to identify gaps in yield between current technology and improved technology aimed at achieving EI.

The experiment was first established at Ponta Grossa, Paraná, in May 2011, by seeding the winter crops to the respective treatment plots. The soil in the area is an Oxisol that has been in a no-till system for 6 years. The experiment had a split-plot design with the main plots involving three types of management systems and the sub plots being three levels of N input plus a control. Different management systems used were: 1) farmer practice (FP) involving a 2-year complete crop rotation cycle of black oats, corn, wheat, and soybean; 2) FP + silage production; and 3) EI of black oats + forage peas, corn, black oats, and soybean. The EI treatment is planned to occur twice, alternating the crop rotation initiation point to permit the production of corn every summer. The levels of N application for corn were 70, 140, and 210 kg N/ha, plus a control with no N added.

The results for dry-matter yield for the winter crops varied from 3,907 for black oats to 5,725 kg/ha for ryegrass. Up to 140 kg/ha of N were applied to the soil for growing winter crops. The summer crops are currently in the area and it is possible to visualize the effect of the winter forage peas in adding nitrogen to the system (lower N response in the corn crop). Soil samples were collected to evaluate the soil physical properties. Also, tissue samples were collected from the summer crop for laboratory analysis. *IPNI-19*

Brazilian Soil Fertility Survey (Phase 1)

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Soil fertility surveys of specific countries or regions are an important tool to ascertain soil chemical properties for adequate crop nutrition. Due to a paucity of such information, the IPNI Brazil program led an effort to put together soil fertility information for Brazil. The plan is to complete this endeavor in three phases. This summary presents results of phase 1, which are also stored in IPNI Brazil database as Brazilian Soil Fertility Survey based on Soil Samples. For this phase, a total of 5,556 soil samples were collected but only 3,365 samples were used to interpret and classify different levels of nutrient sufficiency. For available P, three types of interpretation were necessary (exchange resin (P-Res); Mehlich 1 + clay content (P-Meh); or remaining P in solution (P-Rem)) with all three indicating response to P in the great majority of the samples (86%, 63% and 38% for P-Res, P-Meh and P-Rem, respectively). Simulation of collected data, considering that only soybean crop was grown in all areas, showed a requirement of about 1.5 to 2.0 million tons (Mt) of P_2O_5 for Brazil. For K, the survey showed that 44% of the soil samples had K levels that are considered very low or low in terms of K bioavailability. 78% of the samples presented levels indicating some kind of response to K. Simulations showed that about 2.2 Mt of K_2O would be necessary considering recommendations from EMBRAPA (Brazilian Agronomic Agency) and soybean cropped in all areas. Among secondary nutrients, the survey showed that 76% of the soils would lead to S response, while among the micronutrients considered (Zn, Cu, Mn, and B), the survey indicated low levels of their bioavailability in the great majority of the samples. Interestingly, 98% of soil samples showed a clear trend to some kind of response to B. Phase 2 will deal with results of soil samples utilizing the ion exchange resin methodology, while phase 3 will try to include the highest possible number of soil samples from laboratories around the country. *IPNI-44* ❖

Americas and Oceania Group

Latin America–Southern Cone: Dr. Fernando García

Argentina

The Crop Nutrition Network in the CREA Region of Southern Santa Fe

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The Regional Consortium of Agricultural Experimentation (CREA), a farmer organization based in Southern Santa Fe, has established a network of field experiments with the objectives of: 1) determining direct and residual responses to N, P, S, and where indicated, to K, Mg, B, Cu, and Zn, 2) evaluating recommendation methods for N, P, and S fertilization, 3) identifying the level of deficiency and potential response to nutrients other than N, P, and S, and 4) evaluating the evolution of soil quality under contrasting nutrient management. In 2010-11, two sites within a corn-wheat/soybean (C-W/S) rotation were planted to maize, and four sites within a corn-soybean-wheat/soybean (C-S-W/S) rotation were planted to full-season soybeans.

Excellent climatic conditions at the two maize experiments allowed for high yields. Yield responses to N, P, and S were significant at both sites (average of 6,465 kg/ha, +132%), and responses to nutrients other than NPS were significant at the Balducci site (647 kg/ha, +8%). Soybean yields averaged from 3,400 to 5,200 kg/ha in the four experiments. Responses to N, P, and S were significant at three sites, with average responses of 364, 488, and 448 kg/ha to N, P, and S, respectively. The combined response to NPS at the four sites averaged 1088 kg/ha (+33%).

Considering the 11 seasons with 40 sites under corn, 33 sites under wheat, 52 sites under full-season and double cropped soybean, significant relationships were established between Bray 1 P and P responses, with critical levels between 12 and 20 ppm for the three crops below which P responses are highly probable. Also, significant relationships were established between grain yield and soil N supply as predicted by soil nitrate-N measured at sowing + fertilizer N rate, for maize and wheat.

The analysis of the first years of the Nutrition Network has shown that adequate NPS management increased grain yields, contributed to improved water use efficiency, tended to increase soil organic matter, decreased soil pH, allowed for soil P build-up, and increased profits. Sites will be planted to wheat-soybeans in both rotations (C-W/S and C-S-W/S) during the 2011-12 season. *Argentina-12*

Long-term Nutrient Management Network for Southern Buenos Aires Province

Project Leaders: Fernando García, IPNI Southern Cone and Ernesto Caracoche, ASP Southern Division, Acassuso, Buenos Aires. E-mail: fgarcia@ipni.net

In 2007-08, IPNI and Agroservicios Pampeanos (ASP) established a network of field experiments with the objectives of: 1) determining direct and residual responses to N, P, and S, 2) evaluating recommendation methods for N, P, and S fertilization, and 3) identifying the level of deficiency and potential responses to nutrients other than N, P, and S, such as K, Mg, B, Cl^-, Cu, and Zn. Four sites were planted to wheat at Balcarce, Pieres, Tandil, and Tres Arroyos during the 2010/11 growing season.

Excellent climatic conditions during the 2010-11 growing season allowed high grain yields to be reached. Wheat check yields varied from 3,989 to 5,082 kg/ha, and NPS fertilized yields varied from 5,158 to 8,167 kg/ha. Responses were significant to NP at Balcarce (+2,797 kg/ha, +63%), Pieres (+1,492 kg/ha, +26%), and Tres Arroyos (+3,126 kg/ha, +61%); and to P at Tandil (+1,552 kg/ha, +43%). Grain yield responses were related to low soil nitrate-N, and Bray-1 P levels, and good weather conditions. No responses were observed to nutrients other than N, P, and S. These sites will be planted to full season soybean during the fifth season of evaluation in 2011-12. *Argentina-27*

Evaluation of Enhanced Efficiency Fertilizers for Wheat and Maize

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A field experiment was established for wheat in the 2010-11 growing season at Balcarce, Buenos Aires, to evaluate the performance of N and P enhanced efficiency fertilizers in wheat and maize production at two locations of the Argentinean Pampas. Treatments included N rate x source x timing combinations for wheat.

Dry matter accumulation at physiological maturity as well as final grain yield and grain protein was affected by N rate, but not by application timing and fertilizer product. There was a trend for timing x source interaction, with NutriSphere NTM (NSN) showing higher grain yields than non-treated urea at seeding, indicating that applications of controlled release fertilizers at seeding could be as effective as applications of regular granulated urea at tillering. Field experiments will be established for wheat and maize in the 2011-12 growing season. *Argentina-28*

Response to Zinc in Maize Crop Grown in the Argentinean Pampas

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Project Cooperators: Carlos Michiles and Matias Ruffo

Grain crops of the Pampas region of Argentina, mainly maize, have shown Zn deficiencies. However, research on Zn responses in maize is scarce. The objectives of this research project are to: 1) quantify maize response to Zn in the Pampas region, 2) determine the optimum Zn rate for maize, and 3) validate local Zn analyses and critical levels. Fourteen field experiments were carried out in the 2009-10 and 2010-11 seasons at different locations of the Pampas regions, including: Alejo Ledesma, Chaján, Adelia María, Guatimozin, and Rio Cuarto in Cordoba; San Justo, M. Teresa, Rafaela and Oliveros in Santa Fe; and 9 de Julio, Balcarce, Lincoln, and Gral. Villegas in Buenos Aires. Treatments include NP, NPS, and NPS with different Zn rates (0, 0.5, 1, 1.5, and 2 kg Zn/ha). Fertilizer sources were MAP+ urea (NP treatment), MES10™ (12-40-0-10S; NPS treatment) and MESZ™ (12-40-0-10S-1Zn; NPS plus Zn treatments). N, P and S rates were of 80 kg N, 35 kg P and 20 kg S.

Visual deficiency symptoms were observed in most locations. Results from the 2 seasons of experimentation showed significant grain yield responses in eight of the fourteen sites. Average grain yields for the fourteen experiments were 11,051, 11,283, 11,342, 11,535, and 11,568 kg/ha for the 0, 0.5, 1, 1.5, and 2 kg Zn/ha rates, respectively. Optimum Zn rates varied between 0.5 and 1.5 kg Zn/ha, depending on the location. New experiments will be established at different locations in the 2011-12 growing season. *Argentina-29*

Global Maize Project in Argentina: Balcarce, Buenos Aires

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A long-term field experiment was established at Balcarce, Buenos Aires, in the 2009/10 growing season. The crop rotation is maize-wheat/double cropped-soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and Ecological Intensification practice (EI). Treatments differed by either cultivar, planting date, pest and weed control, or nutrient management practices.

Maize and wheat crops in the 2010/11 season developed under adequate climatic conditions, which favor the expression of an improved potential yield in the EI treatments. Maize yields were 12,647 kg/ha, and 14,726 kg/ha for the FP and EI treatments, respectively, a significant difference of 16% ($p<0.002$). Wheat yields were 3,141 kg/ha for FP and 4,745 kg/ha for EI, again with significant differences between treatments ($p<0.007$). Double cropped-soybean was planted immediately after the wheat harvest in January, and yields of 1,361 kg/ha and 1,165 kg/ha were obtained under the FP and EI treatments, respectively, without significant differences between treatments.

Considering the first 2 years and the three crops involved in the maize/wheat/double cropped soybean, the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP,

but the two treatments did not differ much in the capture of water (ratio of ET/total precipitation). The EI treatment also showed higher N use efficiency and N removal and less negative N balances, but lower partial factor productivity of N as compared to the FP treatment. *IPNI-24*

Global Maize Project in Argentina: Oro Verde, Entre Ríos

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A long-term field experiment has been established at Oro Verde (Entre Ríos) in the 2009/10 growing season. The crop rotation is maize-wheat/double cropped-soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and ecological intensification practice (EI). Treatments differed in either cultivar, planting date, pest and weed control, or nutrient management practices.

Maize yields showed an excellent response to the EI treatment with 5,787 and 9,287 kg/ha yields for the FP and EI treatments, respectively—a significant difference of 60%. Wheat yields were affected by rust (Puccinia triticiae) and were 3,792 and 3,249 kg/ha yields for FP and EI, respectively, with significant differences between treatments. On the other hand, double cropped-soybean yields were similar for both treatments and were 3,128 and 3,123 kg/ha under the FP and EI treatments, respectively.

Considering the first 2 years and the three crops involved in the maize/wheat/doublecropped soybean, the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP, but the treatments didn't differ much in the capture of water (ratio of ET/total precipitation). The EI treatment also showed higher N use efficiency and less negative N balances, but lower partial factor productivity of N when compared with the FP treatment. *IPNI-25*

Uruguay

Exploration of Responses to Potassium in Western Uruguay

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This research is partly based on previous observations of K deficiency and responses in field crops grown within the northwestern Uruguay region. Data from the first 3 years of field work and other studies, including 50 experiments under wheat, barley, maize, soybean, sunflower, or sorghum, indicated a critical range of 0.30 to 0.40 cmol/kg (117 to 156 ppm), below which there is a high probability of response to K fertilization. Integration of soil survey data with this field work has allowed researchers to estimate that 4 million ha have the potential for soil K deficiency in all Uruguay.

On-going field work in 2011-12 is evaluating the effects of K fertilization in winter crops (wheat and barley) and double-cropped soybean. Three of nine experiments located in the traditional agriculture area showed significant yield responses to K application in wheat or barley. Grain yield responses averaged 638, 152, and 220 kg/ha in sites with soil exchangeable levels of 0.24, 0.29, and 0.32 cmol/kg (94, 113, and 125 ppm). These experiments are being evaluated for residual effects on double-cropped soybean grain yields.

Field studies on the dynamics of K release from crop residues, have shown an increased release of K from maize and soybean stover in the early days since residue deposition. The amount of K released was associated with the type of crop and rainfall accumulation. The exchangeable K showed the highest variations in the first 3 cm deep, and was associated with the amount of K supplied by the residues.

Laboratory studies indicated that the K buffering capacity of different agricultural soils vary according to clay content, soil organic matter, and exchangeable Ca and Mg concentrations. An average rate of 184 kg/ha of applied K was needed to increase exchangeable K by 0.1 cmol/kg of exchangeable K in 36 agricultural soils, with a range of 68 to 455 kg/ha. *Uruguay-02* ❖

Americas and Oceania Group

Northern Latin America
Dr. Raúl Jaramillo

Colombia

Nutrient Demand of Oil Palm Hybrids for Tropical America

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This study examines the nutrient demands of the OxG hybrid oil palm and the most adequate tools to calibrate crop fertilization (e.g. foliar critical levels for different nutrients). The nursery phase was initiated in 2010 with two sets of plantlets growing in two locations of Colombia. In each location two parallel studies were carried out with rates of: 1) N, P, and K; and 2) Mg, Ca, and B. Plant growth, nutrient absorption, and leaf physiology were evaluated. The first phase of the study involved independent studies on nursery plants (before transplanting) at two locations. The nursery experiments were carried out in Tumaco (southwest Colombia) having alluvial, relatively high organic matter soils and continuous rainfall; and Meta (center east Colombia) having low organic matter oxisols and seasonal raining. The OxG materials used were accessions obtained from crosses made with *Elaeis oleifera* collected in Brazil. Two different crosses were evaluated in each nursery experiment.

In general the phase I results showed that N controlled the growth of plantlets for the two materials tested in both locations. But for the other nutrients, the response was specific for each OxG material tested, for instance, the demand of K and B in one of the tested materials was larger than the recommended rate for E. guineensis, but the second OxG accession had similar requirements of the African oil palm. As well, the calculated nutrient demand for P and Ca were material specific. The use of K, Mg and B did not produce significant decreases or increases in plant growth (leaf number, leaf area, plant height) in the nursery phase. In the case of B, slight increases were found with the largest quantities used; again, this response was material-specific.

In summary, these results suggest very specific demands of the crop as a function of the material planted, which in practical terms means that each plantation or region may need to develop site-specific studies to fully understand the actual demands of the different OxG materials. The experimental design used may serve as a model for further nursery studies. The second phase of the study was initiated with the transplant of independently managed plantlets at three locations: the Astorga (Tumaco), Hacienda La Cabaña (Casanare), and Unipalma de los LLanos (Meta) plantations. *Columbia-16*

Global Maize Initiative, Colombia

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Project Cooperators: Henry Vanegas (FENALCE General Manager), Carlos E. Molina, and Gustavo Lemos

In 2011, this study completed four consecutive crop cycles at Villa Escocia, and the fifth cycle was planted on October 27. The study had following specific objectives: 1) measure yield differences among different nitrogen management strategies and 2) compare the ecological intensification (EI) management against traditional maize technology.

In 2009-B, the first planted cycle, the average yield in the intensive management was 7.30 t/ha and the traditional management yield average was 5.49 t/ha. Only the treatment with intense management with N in all cycles showed a significantly higher yield (8 t/ha), but this was possibly an artifact as many other treatments suffered from plant lodging. Overall, this cycle indicated a high fertility soil, with small differences within N strategies tested with high or low planting densities.

Cycle 2010-B showed the lowest yield overall as a result of extreme rainfall, this was also the cycle in which the treatments with reduced N application (2/3 cycles) did not receive N. The average grain yield in 2010-B with intensive management was only 6.45 t/ha, while the traditional management average was 5.53 t/ha. The maximum yield was obtained with traditional management N applications in all cycles (8.77 t/ha), which was slightly higher than intensive management with N in all cycles (8.45 t/ha). It was noticeable

by this time a carry-over effect with N management strategies, those treatments with no N or reduced applications (2/3 cycles) had significantly lower yields than N repeated in all cycles.

In the other two crop cycles (2010-A, and 2011-A), the treatments with N application and higher planting density had the highest yields followed by the treatments with N application and low planting density. The values of yield with no N applications declined progressively across the four consecutive crop cycles. *IPNI-38*

Ecuador

Site-Specific Nutrient Management for Soft Corn Varieties in the Highlands of Ecuador

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This study has been conducted for 4 years in the province of Bolivar and together with Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP). A farmers' field day was organized at the ITSA 3 de Marzo school in Guaranda for the local community (June 3, 2011). For this, four plots were prepared: a) Fertilizer recommendation for high yields [50,000 hills/ha; 120, 70, 20, 20 and 10 kg/ha of N, P_2O_5, K_2O, S, and Mg, respectively]; b) Traditional farmer management [37,500 plants/ha; 50, 30, 10, 0, and 0 kg/ha of N, P_2O_5, K_2O, S, and Mg, respectively]; c) Improved farmer management (established to show the benefits of better crop management alone; 50,000 hills/ha with farmer fertilization] and 4) Omission N [50,000 hills/ha; 0 N and all other elements following the recommendation for high yield]. The farmer's field day was attended by about 300 local farmers, agronomists, and agencies representatives. Along with the presentations and visits to the demonstrative plots, a publication was made and distributed to all attendees, which summarizes 4 years of research and shows that together with proper soil conservation and crop management it is quite possible to obtain yields of about 7 t grain/ha, well above the historical average of 3 t/ha.

The project opened a new location in the Imbabura province in the north of Ecuador. To start, as was done in the Bolivar province, several omission plots were established (-N, -P. -K, -S, and -Mg) to check the yield response to individual elements, along with a complete treatment and a control (traditional farmer management). The first planting was made with two replications in a single location at the Cotacachi county. Unfortunately, due to extreme rainfall, many of the plots suffered from an unusual bacteria wilt and the data could not be analyzed as intended.

Following the discussion at the IPNI annual staff meeting, a second planting was made including omission plots for -N, -P, and -K, together with 'addition plot' treatments with an element alone (+N, +P, +K) a zero fertilizer treatment and a regular complete treatment. The sites in this second attempt were in Cotacachi and Otavalo counties. Harvest will be made in the second quarter of 2012. *Ecuador-09*

Best Crop and Fertilizer Management Effects on Yield of Oil Palm in Ecuador

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The activities of this Best Management (BM) project at the Tarragona plantation (Esmeraldas, Ecuador) started in the third quarter of 2009. Tarragona has an average annual precipitation of 3,070 mm and an average temperature of 24.2°C. Soils of this region are slightly acidic (pH 5.07), classified as sandy clay loam Inceptisols, with high organic matter content (4.5%). The site has a severe problem of leaf yellowing, due to cation unbalance that induced K and Mg deficiencies.

The treatments used in the experiment were: a) regular plantation management ('T1'); b) regular pruning, twice a year ('T2'); c) regular pruning plus weekly harvest rounds ('T3'); d) Regular pruning, weekly harvest rounds and balanced fertilization ('T4'); and e) All the previous management plus chemical weed control in plant circles ('T5'). The experiment had a complete randomized block design with four replications. The variables analyzed were fresh fruit bunch (FFB) yield (t/ha), leaf area (sq. m), root dry weight (g), and root mycorrhiza colonization (%).

The 2009 yield showed no differences among treatments and an average yield of 11 t FFB/ha, T2 had about 7 t FFB/ha this year, the lowest record for the study in this location. In contrast, the cumulative FFB production for 2009 to 2010 showed a marked recovery in the T4 and T5 treatments. T4 increased to about 13.3 t FFB/ha, while T5 had 15.0 t FFB/ha, which was 5.6 t FFB higher than T1 (9.7 t). The yield recorded for 2010 to 2011 showed a general yield increase, but the same pattern as for 2009 to 2010, with the highest FFB/ha yields in T4 (18 t) and T5 (17.2 t). T4 yield was about 7 t higher than T1 (11.1 t) and 3.1 t higher than T3 (14.8 t).

Overall the results at Tarragona are similar to those found in Olepsa and indicate that BMPs can increase yields and improve nutrient use efficiency. ANCUPA (Asociación Nacional de Cultivadores de Palma Aceitera) and the Tarragona management will continue this study for at least an additional year, all related costs will be managed by Tarragona and ANCUPA. *Ecuador-13* ❖

Americas and Oceania Group

Australia/New Zealand Region: Dr. Robert Norton

Oceania

Wheat Grain Nutrient Content for Southeastern Australia

Project Leader: Rob Norton, IPNI, Horsham, Victoria. E-mail: rnorton@ipni.net.

Project Cooperators: Alan Bedggood (ACAS Ltd), Robert Wheeler (South Australian Research and Development Institute), Frank Mcrae (Industry and Investment, New South Wales), Angela Clough (Victorian Department of Primary Industries), and Harpreet Gill (Agrisearch Services Pty Ltd.).

Grain nutrient concentrations for macronutrients and micronutrients were analyzed from more than 70 NVT (National Variety Trials) sites across southeastern Australia. All nutrients tested showed significant differences among regions. Values for the macronutrient P were the most variable (3,329 ± 661 mg/kg) and was more than the commonly used value of 2,900 mg/kg. The variation in grain P content could not be related to soil P test, fertilizer application or grain yield although values varied among regions and states. Sulphur and K levels also showed significant differences among regions, while grain zinc (Zn) levels seemed lowest in regions characterized by alkaline soils.

These data suggest that regional or even paddock-based nutrient concentrations may be required when constructing nutrient balances. It may also be useful to use grain micronutrient content as a monitoring tool to indicate the need for fertilizer additions. These results will be published at the Australian Society of Agronomy annual meeting in October 2012. *ANZ-01*

Growth, Yield, and Water Use of Wheat Under Elevated Carbon Dioxide

Project Leader: Glenn Fitzgerald, Victorian Department of Primary Industries, Horsham, Victoria. E-mail: glenn.fitzgerald@dpi.vic.gov.au.

Project Cooperators: Saman Seneweera (The University of Melbourne), Garry O'Leary (Victorian Department of Primary Industries), Sabine Posch (The University of Melbourne), and Michael Tausz (The University of Melbourne).

A significant effect of global warming—both as a cause and an effect—is an increase in global atmospheric carbon dioxide concentration [CO_2]. Elevated [CO_2] increases plant growth and yield—termed the "fertilization effect" because in C3 plants photosynthesis is not carbon dioxide saturated. The extra growth requires additional N, and other nutrients, even though the amount of N in C3 plant tissue grown for long periods under elevated [CO_2] declines, which then results in lower grain N (i.e. protein) content. The plants become more efficient for the amount of N contained, but if the N decline did not occur, the yield response would be larger. There is no information to guide agronomists and breeders towards managing and developing improved varieties to meet and maximize this response. The project has moved from quantifying and modeling the effects of climate change, to investigating the underlying physiological responses and the variation within wheat in those responses so that improved cultivars can be designed for the future.

Seven cultivars of spring wheat were grown at either ambient [CO_2] (~384 µmol/mol) or elevated [CO_2] (700 µmol/mol) in temperature-controlled glasshouses under natural sunlight. Yields increased by 38% on average but some cultivars showed a larger photosynthetic response than others. It was shown that the leaf N content and leaf thickness were correlated with grain yield response. Results of this study show cultivars of wheat do differ in their response to elevated [CO_2] and there are traits that can be used to select cultivars to

ensure optimized response to future atmospheric [CO_2]. This work was undertaken by Lakmini Thilakarathne as part of an MPhil program through The University of Melbourne and has been submitted to Functional Plant Biology for publication.

Water use, as measured by plant transpiration efficiency also alters with higher CO_2 levels, and like photosynthetic response, there were significant differences between two current wheat cultivars and the more efficient water user maintained that benefit even under elevated CO_2. This work was undertaken by Dr. Sabine Tausz-Posch and has been submitted for publication. Dr. Norton continues to work with graduate students and research scientists at The University of Melbourne and the Victorian Department of Primary Industries on these issues as the past project leader. *ANZ-02*

Nitrogen and Sulfur Sources Affect the Response of Canola in Southeastern Australia

Project Leader: Rob Norton, IPNI, Horsham, Victoria. E-mail: rnorton@ipni.net

Project Cooperators: MT Khan (The University of Melbourne), Robert Edis (The University of Melbourne), Deli Chen (The University of Melbourne), and Charlie Walker (Incitec Pivot Ltd).

In cropping systems, the importance of N and S nutrition has been clearly established, particularly for canola. The usual strategy has been to pre-spread gypsum and drill urea in at sowing to meet these demands. It was hypothesized that the use of ammonium sulfate along with urea may enhance both N and S efficiency in calcarosol. A field experiment was conducted in 2011 on a sandy soil at Walpeup in the semi-arid north west of Victoria, an area and soil type that has seen renewed interest for canola production. This experiment aimed to characterize the agronomic aspects of urea, gypsum, and ammonium sulfate under field conditions. Nitrogen and S were applied at different rates, in different ratios, and from different products at sowing.

The applied N significantly increased growth and seed yield, and the crop yield increased more with applied S in the urea plus ammonium sulfate compared to urea plus gypsum strategy. Urea plus ammonium sulfate significantly increased both agronomic N and S efficiency by 4% and 36%, respectively, compared to urea plus gypsum. Irrespective of whether derived from ammonium sulfate or urea, N significantly increased ($p \leq 0.05$) biomass yield and grain yield at flowering stage and maturity stage, respectively. Sulfur responses were not seen at flowering, but ammonium sulfate showed significant increase of grain, straw, and grain yield at 20 kg S ha at maturity stage of canola compared to gypsum. Although two sources of N and S had little effect on growth and yield at the lower rates of N and S, the urea and ammonium sulfate when applied together increased grain yield (12%) over urea plus gypsum at highest level of N and S. There was no interaction between N and S rates indicating that the ratio at which these nutrients were applied was not important in this situation. This research is part of a PhD project undertaken by MT Khan through The University of Melbourne. *ANZ-03*

Nitrogen Dynamics Under Elevated Carbon Dioxide

Project Leader: Deli Chen, University of Melbourne Resource Management and Geography, Melbourne, Victoria. E-mail: delichen@unimelb.edu.au

Project Cooperators: Shukee Lam (The University of Melbourne), and Roger Armstrong (Victorian Department of Primary Industry).

Elevated atmospheric CO_2 affects growth and yield which then affect processes controlling the supply and losses of N to sustain these increases. This research was undertaken to measure the effects of elevated CO_2 on crop N demand, fertilizer N recovery, symbiotic N_2 fixation, residual N availability, and greenhouse gas emissions from cropping systems in southern Australia (Horsham) and northern China using free-air CO_2 enrichment (FACE) facilities and glasshouse chambers. Elevated CO_2 generally increased crop biomass (11 to 84%) and grain yield (10 to 70%) across a range of crops, except when the wheat crop was grown under a hot and dry period, or when legumes experienced P deficiency. Results in the literature indicate that grain N removal worldwide is likely to increase by an average of 17% in crops grown under elevated CO_2.

Wheat was no more effective at sourcing N from fertilizer, so that the CO_2-induced increase in plant N uptake (18 to 44%) was satisfied mostly by increased uptake of indigenous N (19 to 50%) at both sites. A glasshouse experiment showed that incorporating crop residues lowered the recovery from soil. Under FACE conditions in Changping, elevated CO_2 increased the proportion (from 59 to 79%) and the amount (from 166 to 275 kg N/ha) of shoot N derived in soybean. A glasshouse experiment then showed that the rate of N fixation in chickpea, field pea and barrel medic under elevated CO_2 depended on P supply, with improved N fixation to CO_2 occurring only with adequate P supply. Elevated [CO_2] increased emissions of N_2O (108%), CO_2 (29%) and CH_4 from soil at Horsham, with changes being greater early in the season. At the Changping site, elevated [CO_2] increased N_2O (60%) and CO_2 (15%) emission, but had no significant effect on CH_4 flux.

Elevated CO_2, therefore, can be expected to lead to higher overall N_2O emission by 27% and 75% under low N and high N inputs, respectively.

Results of the present research suggest that under future elevated CO_2 atmospheres there will be an increase in crop demand for N. To meet this demand requires higher fertilizer N application rates and the greater use of legume intercropping using locally appropriate agricultural management practices. Increases in the terrestrial C sink may be less than expected as CO_2-induced increase in greenhouse gas emissions will be significant as atmospheric CO_2 rises. *ANZ-04*

Climate Change Will Affect Grain Quality and Micronutrient Content

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Project Cooperators: Nimesha Fernando, Saman Seneweera, Joe Panozzo, Michael Tausz, and Glenn Fitzgerald

The impact of elevated [CO_2] at two different sowing times over 2 years on wheat (cv. Yitpi) grain physical, chemical, rheological quality traits under Free Air CO_2 Enrichment (FACE) was investigated. Most of the grain physical qualities improved under elevated [CO_2], but protein concentration was reduced by 12%. Similarly, most of the grain macro- and micronutrient concentrations were reduced at elevated [CO_2], while total mineral uptakes of N, P, K, Ca, Mg, S, Zn, and Fe were increased. The concentration of grain phytate was reduced at elevated [CO_2], but grain fructan concentration was unchanged. The rheological characteristics of the flour were changed at elevated [CO_2]. The magnitudes of reduction in grain physical, chemical, and rheological quality parameters were greatest at elevated [CO_2] in 2009-TOS_2, which experienced heat stress.

These data suggest that most of the beneficial effects of elevated [CO_2] on grain physical quality are counteracted by its negative impact on grain chemical and rheological quality traits suggesting a negative impact on human health and economy of wheat product-based industries. However, net effect of unchanged fructans and decreasing phytate concentrations should be improved bioavailability of Fe and Zn, which could help to partially offset the negative effects of elevated [CO_2]. Increased nutrient uptake suggests that nutrient management strategies are needed to develop sustainable food production under future climate.

This research was undertaken by Nimesha Fernando, PhD student with The University of Melbourne and has been accepted for publication in the journal Food Chemistry. *ANZ-05*

Effect of Rate and Timing of Potassium on Three Crops

Project Leader: Ross Brennan, Western Australian Department of Agriculture and Food, Albany, Western Australia.
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In a glasshouse experiment, wheat, lupin, and canola were grown on a yellow sandy earth from a field site where the K had never been applied. The Colwell soil extractable K was 26 mg/kg, a soil test level expected to be deficient for the growth and yields of these three crops. Several levels of K, as sulphate of potash, were applied to give a range of K additions from deficient to an adequate supply of K for dry weight of shoots and grain. Fertilizer K was applied at 4 growth stages from 2 to 3 leaves to booting in cereal or bud formation in canola and lupin.

The late application was ineffective to correct severe K deficiency in wheat. To achieve about half the maximum shoot weight at time 3, about 4.5 times more K needed to be applied. Similarly for grain yield (g/pot), to achieve 2 g/pot about 5 times more K needed to be applied. The maximum grain yield was halved by delaying the correction of K deficiency. For lupins, late application was also ineffective to correct severe K deficiency but the effects were not as drastic as for wheat. For grain yield (g/pot), to achieve 2.5 g/pot about 7 times for time 3 and 15 times for time 4 more K needed to be applied. The maximum grain yield was 75% of maximum by delaying the correction of K deficiency to application time 4. Likewise for canola, the late application turned out to be ineffective to correct severe K deficiency. However, the effects were similar to wheat but less drastic than for lupin. To achieve 1.0 g/pot, about 7 times more K was required at time 3 and 15 times for time 4 more K needed to be applied.

The maximum grain yield was about halved by delaying the correction of K deficiency to application time 4. Many of the lower K application rates produced no grain. So, in terms of K responsiveness, for K applied at 2-3 leaf stage, reducing rates from 100 kg K/ha to 50 kg K/ha gave greater (about 20%) yield loss in wheat and canola than in lupin (5% yield loss). *ANZ-07*

Phosphorus Improves Oaten Hay Yields at Long-term Site

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Project Cooperators: Rohan Davies and Peter Howie

Established in 1996, this long-term site at Dahlen, 10 km west of Horsham, has had five rates of N (0, 20, 40, 80, 160 kg as urea) and four rates of P (0, 9, 18, 36 kg as triple superphosphate) applied annually over the past 16 years. The site has been direct drilled and no stubble has been removed or burned. In 2011, the site was sown to oats in mid-May as a hay crop and the standing crop cut on 20 September when the plants were still in the flag leaf growth stage.

The site mean yield was around 6 t/ha of dry matter and the effect of added P was clear with the first 9 kg of P giving a 77% increase in dry matter. Increasing P from 9 to 18 kg gave an additional 24% in dry matter. The higher hay yield was of a lower quality, with lower crude protein, higher fibre content and a lower metabolizable energy content. Despite this, total yield of both energy and protein rose significantly as more P was added. For example, the 9 kg P/ha rate increased the yield of protein and energy by 60%. Like P, applied N had a significant effect on the quality of fodder produced, with the extra N increasing crude protein content from 8.4% (nil N) to 13.1% (80 N). Balancing N and P meant that the yield gains due to the added P also maintained quality by keeping N supply up. The nil effect of applied N on hay yields was surprising, as there was only 26 kg N/ha in the top 60 cm at sowing on the nil N plots and total N demand was around 90 kg by the crop. It seems there was extra N beyond 60 cm, a remnant of the previous applications, leached down with the past two relatively wet years in the Wimmera. *ANZ-08*

Better Fertilizer Decisions for Crops

Project Leader: Simon Speirs, Industry and Innovation Wagga Wagga Agricultural Research Institute, Wagga Wagga, New South Wales. E-mail: simon.speirs@industry.nsw.gov.au

Project Cooperators: Ken Peverill and Doug Reuter

This project was established to improve current fertilizer recommendations by collaborating with national fertilizer industry, grains industry, state agencies, and agribusiness stakeholders. It aims to collate available and suitable N, P, K, and S crop response and soil test data for cereal, pulse, and oilseed crops, and make these data accessible through a searchable online repository. Data have been contributed by private and public research organizations including all the current fertilizer companies and state agriculture agencies that have done experiments over the past 40 years. The data set can then be used by growers and advisors to estimate critical soil test values and response curves for various crop and nutrient combinations.

During 2011, data entry was completed with data from over 4,500 nutrition experiments entered with most data for N and P responses on wheat and barley. A web interface to the database called the "BFDC Interrogator" was developed. The project team met in March and November 2011 to test these calibrations. The plan is that the website will go "live" in June 2012.

Training in the use of the interface was started on a trial basis in October 2011 with a group of agronomists in central New South Wales. This course was supported by the development of a technical manual to describe how to use the Interrogator, as well as materials to support the training of operators. Protocols are being developed to include long-term fertilizer trial data into the database, as well as strategies to maintain the database once the GRDC project funding ceases in June 2012. The project is led by New South Wales DPI, and supported by the Grains Research and Development Corporation. *ANZ-09*

Longerenong Cropping Challenge - Wheat Phase

Project Leader: Rob Christie, Nuseed, Horsham, Victoria. E-mail: robert.christie@au.nuseed.com

Project Cooperators: Mark Slatter (Nurfarm), Steve Drum (Longerenong College), and Peter Howie (The University of Melbourne).

Thirteen groups participated in this agronomy challenge, where advisors were asked to provide crop management plans for the production of a wheat crop on the same plots used for canola in 2010. The management plans allowed agronomists to select variety, sowing time, seeding rate, crop protection strategies and nutrient management plans, as well as marketing plans for the grain. More important than the winning or losing was the sharing of information and experiences among the agronomists as they try out new strategies.

Best yields were over 5 t/ha and modelled yield suggested 6 t/ha so there could have been some unmet potential still on the site. Maybe the very dry September was a problem in achieving this yield potential (YP). The highest wheat yields were for Tylers/Agwise and IPL (no significant difference). Three other groups grew

better than 4.5 t/ha. Tylers/Agwise also achieved the highest gross margin of AUD 564/ha, and four other groups got gross margins over AUD 500/ha. There were no "silver bullets" in the plans, the results here are the consequence of the whole package.

Nitrogen was generally not a limiting factor over the whole this season. The two top yielding groups exceeded the predicted N limit maybe because the crops exploited N deeper than the soil test went. Nitrogen fertilizer recovery in the grain was higher for the higher yielding crops were around 50% and less than 40% for the lower yielding crops.

Up front, N was probably associated with lower grain protein, but yields were generally good. 2011 was a tough year to make decent grain protein—even the high N users tended to stimulate yield more than protein. Lower yields tended to have higher proteins. Phosphorus was generally well supplied, and on average across the site, the P off-take was the same as the amount of P applied. Stripe rust was the main disease; present at varying levels depending on variety susceptibility and use of fungicides. In determining final gross margin, yield seemed more important than price. Keeping costs down was more important than forcing up quality. *ANZ-11*

Tactical Use of Nitrogen in Canola to Manage Risk and Include Break Crops in Northern Wimmera

Project Leader: Felicity Pritchard, PACE Consulting, Horsham, Victoria. E-mail: oilseed@bigpond.com.au

A trial was undertaken to determine if N rates for canola can be reduced in the Wimmera without loss of yield. It also aimed to determine how late N can be topdressed. There was no response to a low rate of N, while 50 kg N/ha when applied at or near sowing gave a 54% yield increase, and 100 kg N/ha application raised yields a further 14%. Nitrogen rate is therefore very important, but timing—when applied even up until early flowering—had little effect. Soil test N at sowing was 41 kg N/ha, and this would have carried the crop through the early growth. The crop showed good recovery from N stress when N was applied as late as early flowering.

Growers in this region base the fertilizer program on expected N demand based on a water limited yield potential. A total 80 kg N/ha/tonne of grain yield—the popular "rule of thumb"—has stood up as the best treatment over a range of timings. However, results from this trial suggest a lower rate (60 kg) can provide similar yields as long as it is applied early.

This field experiment confirmed that canola can respond to late applied N (early flowering) but less efficiently than earlier applied N in a season with a dry spring. *ANZ-12*

Multinutrient Deficiencies in Northern Grains Cropping

Project Leader: Mike Bell, University of Queensland, Kingaroy, Queensland. E-mail: mbell4@uq.edu.au

We continue to see evidence of responses to additional P, K, or S fertilizer applications in winter and summer crops, with a number of sites responding more strongly to combinations of these nutrients (i.e. P and S, or PK and S) than due to individual nutrients alone. This is especially the case where sufficient N is available to allow higher yield targets to be reached. Factors which affect root system efficiency or the ability of root systems to explore large soil volumes (e.g. lesion nematode activity or water logging) will increase the size of yield responses.

In the recent wet summer and winter crop seasons, the reliance on deep placement of P or K has generally been reduced in favor of overall profile (0 to 25 cm) enrichment, but residual effects of deep P applications are still being recorded six crop seasons after application.

It is proposed that application strategies for P and K fertilizer be developed around periodic deep (15 to 20 cm) applications in bands 50 cm apart (or closer), in addition to the current use of starter P applications in the seeding row when Colwell-P tests in the 0 to 10 cm layer indicate a deficiency. Applications should at least meet likely crop removal in grain until the next application event, while redistribution of deep applied nutrient in crop residue will enrich the topsoil layers. Applications of the more mobile N and S can be made to target individual crops and yield targets as at present. *ANZ-13* ❖

Asia and Africa Group

Africa

Dr. Shamie Zingore

Maize Intensification in Mozambique (MIM) - An Industry Response to the Abuja Declaration on Fertilizer for an African Green Revolution

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For 4 years, IPNI has been working in Mozambique with IFDC (International Center for Soil Fertility and Agricultural Development) to help small-holder farmers improve their livelihood through intensifying maize production. Our objective is to demonstrate the use and value of fertilizers and other 'best agricultural practices' (i.e. improved seed, crop protection, tillage systems etc.) to help small-holder farmers in Mozambique move from subsistence to commercial farming. This project compliments regional IFDC activities linking farmers with agri-input suppliers and traders, NGOs, farmers' organizations, extension services, and other partners, thus strengthening the value chain of maize production in the country.

In 2011, several demonstrations on productive farming areas in Manica and Sofala Provinces in Central Mozambique and Zambezia Provinces in Northern Mozambique were conducted. Hybrid maize produced about 1.2 t/ha without fertilizer application, and performed better than farmer-saved seed varieties which produced only 0.8 t/ha. The application of NPKS fertilizer and the use of hybrid seed tripled maize yields from that of the normal practice of farmers planting saved seed and not using fertilizer. The use of NPKS fertilizer also gave a net income of USD 400, indicating high economic returns to intensification of maize production in Mozambique. Costs for management of demonstrations were 30% lower for conservation tillage than conventional tillage. However, yields and net profits under conservation tillage were on average 20 to 30% lower than those under conventional tillage. The poor performance of conservation agriculture was associated mainly with poor weed control.

The national average production for maize is less than 1 t/ha, and results from the demonstrations showed that the yields can be increased to 3 t/ha with moderate rates of NPKS fertilizer and hybrid seed. New nutrient omission trials have been established to derive balanced nutrient requirements and develop site-specific nutrient management recommendations for variable soil fertility conditions in project sites. The International Fertilizer Industry Association (IFA) and the International Potash Institute (IPI) are also providing financial support for this project. *IPNI-11*

Evaluating the Impact of Soil Fertility Heterogeneity on Maize Nutrient Requirement and Productivity in Small-holder Farming Systems

Project Leader: Regis Chikowo, University of Zimbabwe Department of Soil Science and Agricultural Engineering, Harare, Zimbabwe. E-mail: rchikowo@agric.uz.ac.zw.

Small-holder farming systems in Sub-Saharan Africa are characterized by large variability in soil fertility at both farm and landscape levels, leading to variable crop productivity and crop response to additions of fertilizer. Consequently, large yield gaps arise from soil fertility differences between fields due to a combination of inherent and management factors. IPNI initiated a coordinated maize project in 2010, and has been collaborating with the University of Zimbabwe to assess maize production potential and develop site-specific nutrient management practices for variable soil fertility conditions in Eastern Zimbabwe. The project is implementing nutrient omission trials located at multiple sites, to identify which of the macronutrients (N, P, and/or K) are limiting maize growth, and to determine possible other constraints related to soil secondary and micronutrients and soil acidity.

Strong effects of nutrient application on maize yield were observed in the first season despite diminished responses due to long dry spells. The project has established three categories of fields that respond differently to application of nutrients: (i) degraded soil with less than 0.45% soil organic matter that showed a small yield response to fertilizer application; (ii) medium fertility fields that showed moderate responses to N, P,

and K; and (iii) high fertility fields that showed strong responses to N, P and K. Yields with no fertilizer were less than 1 t/ha for all fields, while maximum yields were obtained when all macronutrients were applied. The yield with NPK ranged from 1.3 t/ha in degraded soils to 2.9 t/ha in medium fertility fields to 3.8 t/ha in the high fertility fields.

The project results highlight the strong effects of soil fertility variability on maize productivity and the need to balance N, P, and K supply to optimize maize productivity. Efforts to intensify maize production in north-east Zimbabwe using NPK fertilizers should target the fields in the medium and high fertility categories, while long-term strategies to restore productivity in degraded fields will be necessary to make fertilizer use viable. Project results will be used to map the distribution of different fields in north-east Zimbabwe and develop decision support tools for use by extension systems to help farmers use fertilizer resources efficiently. *Zimbabwe-01* ❖

Asia and Africa Group

China

Southwest Region: Dr. Shihua Tu

Cucumber Yield, Nutrient Use Efficiency, Economic Returns and Soil Phosphorus Forms as Affected by Fertilization and Irrigation Systems in Yunnan

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This ongoing study initiated in 2010 continued to investigate the effects of different fertilizer practices on yield, economic return, and nutrient use efficiency of cucumber, one of the most commonly grown vegetables in Yunnan. The goal was to determine optimal fertilizer rates for cucumber production in the region. The experiment consisted of 26 fertilizer treatments involving different rates of N, P, and K, each receiving two types of irrigation (drip and traditional) and replicated three times. In addition, there were two forms of K (KCl and K_2SO_4) used in the study to evaluate source differences. Based on the results obtained in 2010, fertilizer rates in 2011 were adjusted to 0, 120, 240, and 360 kg of N, 0, 60, 120, and 180 kg of P_2O_5, and 0, 195, 390, and 585 kg of K_2O per hectare, of which rates of N and P were lowered and K was raised, and applied several times in a 10-day interval starting from seeding.

Results showed that 2011 cucumber yields were higher than those in 2010, especially for drip irrigation. Drip irrigation increased cucumber yield by 7,960 to 11,380 kg/ha (20 to 30%) and saved water by 563 m^3/ha (40%) compared to the traditional irrigation. The optimal (OPT) fertilizer treatment tested was 240-120-390 kg N-P_2O_5-K_2O/ha under both irrigation systems in 2011, a reduction of 60 kg N/ha and 30 kg P_2O_5/ha, but an increase of 30 kg K_2O/ha compared to rates used in 2010. The net income of OPT was USD 14,787 for drip irrigation and USD 11,774 for traditional irrigation. The agronomic efficiencies of N, P, and K fertilizers were 45, 53, and 36 kg cucumber/kg nutrient under drip irrigation and 36, 46, and 31 under the traditional irrigation, respectively. Potassium chloride produced higher cucumber yield than K_2SO_4 at all K rates in 2010, but this was reversed in 2011, possibly due to continued omission of S over for two years. This study revealed that in addition to meeting the proper 4R management of the crop, other agronomic practices such as proper irrigation method were crucial to improving crop yield and fertilizer use efficiency. *Yunnan-BFDP-08*

Effect of Balanced Fertilizers on Papaya Yield and Quality in Guangxi

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Project Cooperator: Zhou Liuqiang

This study, initiated in 2010, continued to evaluate the effects of different fertilizer treatments on fruit yield and quality of papaya grown in Nanning City, Guangxi. There were seven treatments including: an optimal treatment (OPT) and treatments individually omitting N, P, K, Mg, B, and Zn within the OPT. Since papaya response to Mo was insignificant in the previous year, it was omitted from this year's design. The OPT treatment remained the same as set in 2010 at 900-190-960 kg N-P_2O_5-K_2O/ha, plus 130 kg MgO/ha, 4.0 kg borax/ha, and 4.0 kg zinc sulfate/ha.

Papaya yields significantly responded to N, P, and K application at two sites in spite of the considerable difference in their productivity. Yields were reduced by 18.6 t/ha (-41.6%), 8.6 t/ha (-19.1%), and 5.7 t/ha (-12.6%) with omission of N, P, or K, respectively. Omission of Mg or Zn reduced papaya yield by 3.4% and to 4.5%, respectively, while omission of B had little effect on yield, implying that the critical value for B needs to be adjusted as soil testing did indicate existing deficiencies. Agronomic efficiencies for different fertilizer application were 20.7 kg fruit/kg N; 44.8 kg fruit/kg P_2O_5; 5.9 kg fruit/kg K_2O; 12 kg fruit/kg MgO; 2,200 kg fruit/kg Zn, and 1,300 kg fruit/kg B, respectively.

Based on the two-year results of OPT treatments, 1,000 kg of papaya fruit requires 3.3 to 4.2 kg of N, 1.3 to 1.8 kg of P_2O_5, 9.0 to 11.1 kg of K_2O, 1.4 to 1.8 kg of MgO, 7.4 to 9.8 g of Zn, 2.7 to 3.6 g of B, respectively. *Guangxi-BFDP-08*

Effect of Potassium Rates on Litchi Quality in Guangdong

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This 3-year study, initiated in 2009, aimed to investigate the effect of different ratios of K to N on litchi yield and quality in Guangdong province. There were five K: N ratios employed ranging from 0.6 to 1.2 based on the fixed N rate of 500 kg N/ha and P rate of 150 kg P_2O_5/ha. Appropriate amounts of Ca, Mg, Zn, B, and Mo fertilizers were added to each treatment as identified by soil test and previous studies. The popular litchi cultivar, Feizhixiao, was selected for the field experiment. All nutrients were applied four times in the odd years: after harvest, before blossom, at young fruit setting and fruit expansion, and two times in the even year: after harvest and between young fruit setting and fruit expansion. The results obtained from this experiment along with other related studies will be used to develop the best nutrient management for litchi in southern China.

Results showed that the K: N ratio at 1:1 generally favored all the growth parameters of litchi such as phonological index, enzyme activity, plant hormones, fruit yield, and quality. The parameters tended to gradually become unfavorable as the K: N ratio deviated from 1:1. The contents of hydrogen peroxidase and starch in leaf, indoleacetic acid (IAA) in male flower, and fruit yield were the highest in the treatment of K: N ratio at 1:1. Further, the fluorescent index of chlorophyll was moderate in late April and the highest in late November. The percent of flowering trees and flowering branches at blossom, contents of Abscisic Acid (ABA) and zeatin (ZT) in male flower as well as ZT in female flower were at moderate levels while ABA contents in female flower were the lowest. Amino acids that are believed to govern fruit palatability consisting of delicacy, sweetness, and fragrance (mainly from aromatic amino acids) were relatively richer than the other treatments. The remaining parameters appeared to be similar in all treatments. Since economic benefit is usually closely correlated to yield and input cost, this treatment resulted in the highest net income of USD 9,040 in 2010 and USD 10,849 in 2011. This study demonstrates that optimal fertilization is crucial and effective in improving litchi yield and farmer income. *Guangdong-BFDP-09*

Effect of Different Fertilizer Treatments on Chili Pepper Production in Hainan

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The study continued to verify the optimal fertilizer rates tested in 2010 for chili pepper, one of the most widely grown vegetables during winter on this tropical island, and the results will be used to guide fertilizer application for local technicians and vegetable growers. The experiment consists of six rates of N (0, 300, 375, 450, 525, 600 kg N/ha), P (0, 60, 120, 180, 240, 300 kg P_2O_5/ha) and K (0, 225, 300, 375, 450, 525 kg K_2O/ha). The rates were further fine-tuned based on the yield results from the previous field experiments. The source, timing, and placement of the fertilizers, as well as field management remained the same.

Results showed that the chili pepper yields significantly increased with increased rates of N, P, and K, but leveled off at 300 kg N/ha and 300 kg K_2O/ha. Though the rate of 180 kg P_2O_5/ha produced the highest pepper yield, the increment was modest. The result verified that 300 kg N/ha plus 300 kg K_2O/ha were the optimal rates for chili pepper in Hainan on acid, sandy soils. This fertilizer combination could produce 65 t/ha of chili pepper and net income of USD 11,391. Furthermore, it also achieved the highest agronomic efficiency for N (147 kg pepper/kg N) and K (32 kg pepper/kg K_2O). Based on the two years of experiments, recommendations for NPK fertilization for chili pepper on the Hainan Island can be 300-60-300 kg N- P_2O_5-K_2O/ha. If soil testing indicates a high soil P, P fertilizer can be omitted from the fertilizer program every other crop season or until further study is completed related to P use. *Hainan-BFDP-08*

Nutrient Losses from Sloping Lands as Affected by Nitrogen Sources and Surface Mulch in Sichuan

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The objective of this project was to further evaluate the effects of different N sources and surface mulching methods on corn yield and nutrient losses from Sichuan's sloping farmlands during the summer rainy season. There were four N sources including ammonium N (ammonium bicarbonate, ABC), nitrate N (calcium nitrate), amide N (urea), and controlled-release (CRU) urea and three types of surface mulching (no mulch, wheat straw, and plastic film) employed in the field experiment. The fertilizer rates were 300-150-150 kg N-P_2O_5-K_2O/ha based on the previous experiments.

Results showed that mulching the soil with wheat straw or plastic film significantly increased corn yield by 6.4% or 7.2 % compared to the no mulch treatment. This further confirmed that any methods that could conserve more soil moisture and prevent soil erosion and nutrient losses could produce more corn yield on the non-irrigated sloping lands.

Among the four N sources without surface mulch, CRU produced the highest corn yield, followed by urea, calcium nitrate, and ABC. When combined with surface mulch, all N sources significantly enhanced corn yields. It is of interest that CRU and ABC were equally superior to urea and calcium nitrate on corn yields. Ammonium bicarbonate use under wheat straw mulch slightly reduced corn yield compared to ABC under plastic mulch. Ammonium bicarbonate, an inferior N source, once dominated China's N fertilizer market, but today is of least importance, performed the best under surface mulch, indicating that different agronomic practices can affect the performance of a fertilizer considerably. By further analyzing amounts of soil erosion and nutrient losses caused by different treatments, we determined that mulching treatments significantly reduced nutrient losses through reduced soil erosion (44 to 58%) and reduced leaching or surface runoff (4.1 to 20.3 mm), enhanced N uptake by corn and finally corn yields, the same trend reported in the previous years. *Sichuan-BFDP-09*

Response of Chinese Cabbage to Different Timings of Fertilizer Application in Chongqing

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Traditionally, P and K fertilizers are used as basal application to most crops, if not all. It is unclear what extra benefit would accrue when these two fertilizer are used in split applications at different growth stages of a crop. Thus, this study aimed to investigate the effect of split application of P and K along with N fertilizers on yield and quality of Chinese cabbage in Chongqing, China in 2011. There were six fertilizer treatments combining equal rates, but different timings, of N as urea, P as mono-potassium phosphate, and K as KCl at 300-90-150 kg N-P_2O_5-K_2O/ha. The six treatments included: (1) the conventional timing of fertilizer application (i.e. 100% of P and K fertilizers applied basally, N fertilizer split between basal and top dressing at rosette, cupping, and the fast growing stage; (2) N and P fertilizers split using the above mentioned stages and only K fertilizer was applied basally; (3) N and K fertilizers were split as above and only P fertilizer applied basally; (4-6) all N, P, and K fertilizers were split in above mentioned stages, but with three different allocation percentages.

Results showed that at the same N, P, and K fertilizer rates, the conventional timing of fertilizer application produced the least cabbage yield, while the treatment splitting N, P, and K fertilizers basally at 20% N, 30% P_2O_5, 30% K_2O, and topdressing only at rosette stage at 40% N 40%, 30% P_2O_5, 30% K_2O and cupping stage at 40% N, 40% P_2O_5, 40% K_2O produced significantly higher yield than the other treatments. All the other treatments had the similar yield level with non-significant differences. Further, all the splitting treatments enhanced quality parameters by 2 to 5% for vitamin C, 13 to 33% for reducing sugar, 3 to 28% for amino acids, and 0 to 26 % of reduction for nitrate N compared to the conventional timing of fertilization. The highest yield treatment also improved the cabbage quality by enhancing contents of vitamin C and reducing nitrate N in the leaf head, slightly decreasing reducing sugar and amino acids compared to the other splitting treatments. *Chongqing-BFDP-11-01*

Response of Maize under Plastic Mulch to Controlled Release Urea (CRU) in Yunnan

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The majority of field controlled-release urea (CRU) experiments conducted on maize in recent years were arranged in north China where 80% of maize in China is grown. In 2011, a field experiment was carried out in Yunnan, a big maize producer in south China, to investigate performance of CRU in a high fertility sloping land soil under plastic mulch in humid climate with irregular drought spells in summer. The experiment included four N rates (0, 105, 157.5, and 210 kg N/ha) replicated three times. Each rate of N was tested as paired CRU and regular urea (RU) treatments for strict comparison of CRU effect. Two split N treatments were also included, one with 40% RU basal at seeding and 60% as a top-dressing 53 days after seeding, compared with 40% RU and 60% CRU both applied basal at seeding. All treatments received equal rates of P and K fertilizers that were used as basal application.

Results indicated that all the CRU treatments produced higher maize yields compared to its counterpart RU treatments. The yield increase, however, was not statistically significant, except the CRU versus RU at the full N rate (210 kg N/ha). Maize yields were increased with an increase in N rates and leveled off at 157.5 kg N/

ha for RU and at 105 kg N/ha (50% of the full N rate) for CRU. Agronomic efficiency of both CRU and RU decreased with increasing increments of N application, ranging from 9.5 to 12.6 kg kernels/kg N for CRU and 3.1 to 8.4 kg kernels/kg N for RU. Nevertheless, some of the CRU granules remained intact or with partial N release at harvest time due to protection of the plastic mulch on the soil surface from rainwater infiltration, resulting in inefficient use of CRU by maize and underestimated maize response. Thus, even in this humid climate, the right method of CRU placement needs further study to safeguard complete N release from the coating during the maize growing season. *Yunnan - BFDP -11*

Response of Winter Rapeseed to Controlled-Release Urea in Sichuan

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The objective of this field experiment was to evaluate the response of winter rapeseed to controlled-release urea (CRU) under rain-fed conditions in Sichuan Basin. The deliverables from the project will be the impact on crop yield, N uptake, and economic benefit. The field experiment in 2011 was conducted on an alluvial loam soil with four N rates (0, 90, 135, and 180 kg N/ha) and three replications. Each rate of N was tested as paired CRU and regular urea (RU) treatments for strict comparison of CRU effect. Two split application treatments were included, one with 40% RU basal at transplanting and 60% RU top dress one-month after transplanting, and the second split used 40% RU and 60% CRU both applied at transplanting. All treatments received equal rates of P and K fertilizers that were used as basal application.

Results showed that at the same N rate, the RU treatment always produced much higher or significantly higher rapeseed yield than the CRU treatments. The RU 40%+CRU 60% applied as basal application achieved the highest seed yield among all the treatments. Rapeseed yield increased with an increase in N rate and leveled off when N rate was above 135 kg/ha for RU, but with no yield drop for CRU. This implies that under conditions without irrigation, a dry growing season (accumulative precipitation of 110 mm, but unevenly distributed in 7 months) severely restricted N release from the CRU and thus, rapeseed growth. As a result, CRU could not supply sufficient N to rapeseed no matter what N rates there were in dry season. Accordingly, all the RU treatments had higher N recovery by 4 to 10% and agronomic efficiency by 1 to 2 kg seed/kg N compared with its counterpart CRU treatments. The result further suggested that though CRU is an excellent N fertilizer in wet or irrigation conditions, caution should be taken when it is used under dry season with no irrigation. *Sichuan-BFDP-08*

Right Fertilizer Timing Promoted Sugarcane Yields in Guangxi

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Project Cooperators: Liuqiang Zhou and Rulin Xie

In order to showcase the effect of right fertilizer time on sugarcane yields to growers, industry, technicians, and fertilizer retailers, educational field trials were conducted in a sugarcane base located in Laibin, Guangxi in 2011. The field trials consisted of four treatments with different combinations of fertilizer timing: basal + topdress at tillering stage, basal + topdress at cane elongation stage, basal + topdress at tillering stage and at cane elongation stage, and basal + topdress at seedling stage and at cane elongation stage (the farmers' practice). All the treatments used the same source and rates of fertilizers: 450-135-320 kg of N-P_2O_5-K_2O/ha. The trials were used as an on-site training site for the above mentioned groups in 2011.

Results showed that the treatment of basal + topdress at tillering stage and at cane elongation stage produced the highest cane yield, 3.7 to 6.0 t/ha (7.8 to 8.5%) more than the farmers' practice. Net income was increased by USD 468 to 496/ha (7.7 to 8.5%). The other two treatments also increased cane yields and net income compared to the farmers' practice, but significantly less than the treatment of basal + topdress at tillering stage and at cane elongation stage. Thus, this treatment can be considered as the best timing combination for sugarcane production in Laibin region. The trials convinced local farmers that the effect of properly timing of fertilizers can generate significant improvements in sugarcane yield and net income by using the same fertilizer source and application rates. *Guangxi-BFDP-11*

Impact of Improved Nutrient Management on Potato Yield and Quality in Chongqing

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Project Cooperator: Shuai Wang

Potato is a staple food for mountain dwellers particularly in Chongqing, accounting for one-fourth of total foodstuff consumed annually. In those remote regions, potato yield and quality are usually low mainly due to shortage of good variety, nutrient management, and other related agronomic practices. Thus, how to improve potato yield and quality through balanced fertilization is of great importance for both better income and human nutrition. For this purpose, two field experiments were conducted on two soils, an acid, yellow earth soil with N and K deficiencies located in Wushan County, and another strongly acid soil (pH 4.1) developed from limestone with N, K, and Ca deficiencies located in Fengdu county. The experiments consisted of 11 treatments with three rates of N (75, 150, and 225 kg/ha at Wushan site; 90, 180, and 270 kg/ha at Fengdu site), four rates of P (0, 37.5, 75, and 112.5 kg P_2O_5/ha at Wushan site; 0, 45, 90, and 135 kg P_2O_5/ha at Fengdu site), and four rates of K (0, 75, 150, and 225 kg K_2O/ha at both sites) and replicated three times. Lime was amended to the strongly acid soil at 1,500 kg/ha. The optimal treatment (OPT) was set at 150-75-150 kg N-P_2O_5-K_2O/ha at Wushan site and at 180-90-150-100 kg N-P_2O_5-K_2O-lime/ha at Fengdu site as identified by soil testing.

Results showed that potato yields at both sites significantly increased with an increase in N, P, or K rates and reached the highest yield (39.2 t/ha at Wushan and 27.2 t/ha at Fengdu) with the OPT treatment. The OPT produced 2.5 t/ha (6.4%) or 12.2 t/ha (31.2%) of commercial potato tubers more than the omitting P or K treatment at Wushan site, and 5.9 t/ha (22.8%) or 3.4 t/ha (13.3%) more than the omitting P or K treatment at Fengdu site, respectively. Omission of lime from the OPT significantly reduced potato yield by 10.7 t/ha (41.7%), the highest yield reduction in the experiment. It further demonstrated that contents of amino acids, proteins, and starch in potato tuber were generally increased quadratically with an increase in N, P, and K rates. However, vitamin C tended to decrease with increased N rates, while showing a positive response to P rates and not being influenced by K rates. *Chongqing-BFDP-11-02*

Yield Response of Kidney Bean to Different Nutrients in Guizhou

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The objective of this study was to evaluate different nutrients on yield and quality of kidney bean, one of the main summer vegetables in Guizhou. There were eight fertilizer treatments consisting of no fertilizer (CK), an optimal treatment (OPT) and treatments individually omitting N, P, K, Mg, B, and Mo within the OPT. The results obtained from this experiment and some other related experiments will be used to develop the best nutrient management for kidney bean in the region.

Kidney beans responded to all nutrients except Mg in the field experiment. Yields were reduced by 3.64 t/ha (-14.3%), 5.5 t/ha (-21.7%), and 4.4 t/ha (-17.4%) with omission of N, P, and K, respectively. Omitting Mo and B reduced kidney bean yield by 4.01 t/ha (-15.7%) and 4.07 t/ha (-15.9%), respectively, while omission of Mg only reduced kidney bean yield by 0.7 t/ha (-2.8%). The no fertilization (CK) treatment produced the lowest kidney bean yield of 15.4 t/ha, accounting for 60% of the OPT yield, implying low soil fertility and importance of balanced nutrients amendment to boost kidney bean yield on the studied soils. Quality analysis of kidney beans showed that crude protein content was reduced by 7% and 9% with omission of K and N, respectively, and by 5% with omission of P, Mg, and B each. No influence on kidney bean's protein content was observed with the omission of Mo. *Guizhou-BFDP-11* ❖

Asia and Africa Group

China

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Balanced Fertilization Strategy for High Wheat Yields in Anhui Province

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Wheat is the main food crop grown in Anhui province with a total sowing area of 2 million ha annually. Anhui's wheat average yield (3,195 kg/ha) was 18.7% lower than the average yield of the country (3,932 kg/ha). One of the reasons for lower yield is unbalanced fertilization. Field experiments were conducted at Linquan and Mengcheng counties by the Soil and Fertilizer Institute, Anhui Academy of Agricultural Science in 2011 to demonstrate the benefits of balanced fertilization.

Results showed a remarkable response of winter wheat seed yield and profit to balanced fertilization. Wheat yield was 7,216 kg/ha with the optimal treatment (180-75-90 kg/ha of N-P_2O_5-K_2O) while omitting N, P, K, and NPK reduced wheat yields by 19.3%, 9.8%, 9.6% and 30.6%, respectively. Similarly, profits were also reduced by USD 420/ha, 214/ha, 208/ha, and 607/ha, while omitting N, P, K, and NPK, respectively. The researchers recommend 180-75-90 kg/ha as the optimum fertilization rate of N, P_2O_5 and K_2O, respectively, for wheat grown in Anhui province. This optimal rate should increase wheat yield by average 15% over farmers' common practice. *Anhui-18*

Study and Demonstration of Balanced Fertilization in Cotton in Anhui

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Project Cooperators: Ma Cheng-ze, Zhang Li-gan, He Fang, and Tang Xiao-qiang

Anhui province is one of the major cotton producing provinces in China with annual cotton planting area of 400,000 ha. Thus, the study of nutrient limiting factors and scientific fertilization technology for cotton is of great significance in Anhui.

A field experiment was conducted in 2011 in Wuwei county by Anhui Agricultural University. Five treatments: a) OPT (N-P_2O_5-K_2O = 225-150-225 kg/ha + $FeSO_4$ 22.5 kg/ha + $MnSO_4$ + $ZnSO_4$ 7.5 kg/ha), b) OPT-N, c) OPT-P, d) OPT-K, and e) CK (no fertilization) were used in the experiment with three replications. The plot area was 20 m^2, and planting density was 18,000 plants/ha. The seedlings were planted on April 20, and the crop was transplanted on May 15 in 2011.

The results indicated N as the most important nutrient limiting factor for cotton in this region followed by K. The number of bolls, height, fruit branches, and boll weight of OPT-N treatment decreased by 42.2%, 17.8%, 16.7%, and 10.6%, respectively, when compared with the OPT treatment. Similarly, the number of bolls, height, and fruit branches of OPT-K treatment decreased 25.3%, 6.4%, and 11.1%, respectively, compared with the OPT treatment. The seed yield of the OPT (4,075 kg/ha) was 36.6% higher than OPT-N. Potash application increased cotton bolls, boll weight, and lint yield significantly. Based on applied N at 225 kg/ha and P_2O_5 at 150 kg/ha, the best K_2O application rate was 337.5 kg/ha with seed yield of 4,195 kg/ha and better cotton quality (fiber length was 29.7 mm, increased 14% than that of OPT-K treatment). *Anhui-19*

Environmentally Sound Fertilization Technology for Vegetables and Banana

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Project Cooperators: Li Juan, Kong Qingbo, and Chen Yanhua

Vegetable planting area in Fujian Province has reached 670,000 ha with a total production of 14,530,100 t, and is valued at USD 33 billion. However, imbalanced fertilization practices usually followed by farmers here affect the environment negatively. This study was conducted by the Soil and Fertilization Institute of Fujian Academy of Agricultural Science with the objectives of demonstrating efficient fertilization technology for vegetables and banana in Fujian.

Results showed that balanced fertilization helped attain maximum lettuce yield of 46 t/ha (8.7% increase over farmers' practice) with net income of USD 1,509/ha. For banana, the results showed that average yield of balanced fertilization plots was 43.8 t/ha. Nitrogen fertilization contributed banana yield 0.8 to 4.2 t/ha, P fertilization contributed 0.2 to 4.4 t/ha and K fertilization contributed 1.2 to 3.8 t/ha over farmers' practice. A control plot without fertilizer revealed that soil indigenous nutrient supplies contributed about 50% of banana yield.

A long-term field experiment has been running in Pinghe county since 2008 with green beans-cucumber-early rice rotation. Unfertilized plots showed that the soil indigenous fertility contributed about 61% to vegetable yield and about 80% to rice yield. The residual effect of N and P fertilizers applied to the two vegetable crops in rotation, had a positive impact on the yield of early rice yield. No fertilization in the rice growing season obtained the highest economic profit with less than 10% lower yield, reflecting the large supply of residual nutrients left after the two vegetable crops. After cucumber, soil NO_3^--N and P concentrations of soil water were 1,125 mg/L and 2.267 mg/L, and after rice planting season, it dropped to 143.5 mg/L and 0.435 mg/L. Therefore, in this rotation, rice planting not only greatly increased fertilization efficiency, but also greatly reduced the NO_3^--N and P concentrations of soil water. In this rotation with optimum fertilization treatment, N loss was reduced by 67.7 kg/ha and N use efficiency increased from 45.1 to 65.6%, while P loss reduced by 6.6 kg/ha and P use efficiency increased from 17.9 to 26.5% over farmers' practice. *Fujian-10*

Study on the Plant Nutrition Characters and Management Technology for High Yield and Quality of Peanuts

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Project Cooperators: Liao Boshou, Li Jun, and Ma Hao

Peanut is an important oil and cash crop in China that was sown in 42.5 M ha area with a total production of 14.29 M t in 2008. Peanut oil accounted for 23% of the domestic vegetable oil production in China, next only to Rapeseed oil. Hubei is one of the main peanut growing provinces in China. This study on balanced fertilization of peanut was successfully carried out by the Oil Crops Research Institute, Chinese Academy of Agricultural Sciences in Yicheng, Xiangyang, and Hong'an counties of Hubei province in 2011.

Results indicated that K and lime are the main limiting factors for peanut growing in these regions. Compared with the common farmers' practice, an additional application of potash increased peanut yields by 6.9% while lime application significantly increased summer peanut yields by 23%. Field experiment results showed that foliar application of Fe, Mn, and Mo had no significant effect in reducing peanut's disease of leaf etiolation. Film-mulching technology increased seed germination, seedling number, and yield by 14.3, 17.1, and 28.4%, respectively, than no mulching treatment. *Hubei-28*

Potassium Application to Improve Yield and Quality of Chestnut

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Chestnut (Castanea mollissima Blume) is a local, dried fruit tree in Hubei province with planting area of 354,000 ha and annual production of 125,000 t. The tree is widely distributed throughout the province because of it's strong adaptability and has a high value fruit. In order to increase chestnut yield and quality, this project was conducted by the Hubei Academy of Forestry Science. Field experiments were carried out in Macheng and Luotian counties of Hubei in 2011.

Results indicated that potash fertilization significantly increased chestnut yield. When N was applied at 200 kg/ha and P was applied at 120 kg P_2O_5/ha, increasing levels of K application (75, 150, 225, and 300 kg K_2O/ha) increased chestnut yields to 5.9, 6.8, 7.2, and 7.5 t/ha, which were 12.8, 30.7, 37.8, and 43.4% higher than yield without K application. The net incomes (USD) with varying levels of K application also increased to 933, 2,312, 2,819 and 3,163/ha, respectively. Based on the results, the optimum K application rate ranged from 150 to 225 kg K_2O/ha was recommended for fruiting chestnut trees. With the optimum rate of K application, chestnut yield can be increased on average from 1,600 to 1,900 kg/ha. *Hubei-32*

Soil Fertility Evaluation and Management Strategies for Garden Plants

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Wuhan Botanical Garden, Chinese Academy of Science, has been carrying out a project since 2009 to assess soil fertility and management strategies for successfully growing garden plants in Hubei province. For this, a primary survey was done on garden plants in the province, and a total of 300 soil samples were taken from the 10 main cities of Hubei and analyzed in 2010 and 2011.

Results from the survey and soil analysis indicated that the garden plant soil fertility was low in the 10 cities of Hubei, associated with compacted soils of bad structure. Both soil organic matter and available N and P were low in the soils, while soil pH was rather high, when compared with farmland soils. Most of the areas growing garden plants are not fertilized, although the recommended ratio of N:P_2O_5:K_2O fertilization for common garden flowers is 1:0.4:0.75 in Hubei. We conclude that some research and demonstration studies on balanced fertilization in garden plants are urgently required. *Hubei-33*

Effect of Soil Fertility Evaluation on the Weed Succession Process

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Ecological adaptation of plants is the result of mutual interaction between plants and their surrounding environment. It reflects not just the adaptive ability of plants, but also the effect of environment on the plant community. In agro-ecosystems, soil conditions tend to change under long-term fertilization that loads natural selection pressure on weeds. And then the weed occurrence frequency, weed community component and diversity, and weed seed bank were further influenced by reconstructed interspecific competition relationships. To study the effect of soil fertility on weed succession, three experimental sites were established in 2008 by Wuhan Botanical Garden, Chinese Academy of Science in Honghu and Yichang counties of Hubei, and Fuzhou city of Fujian. A biodiversity survey of farmland weed communities at the sites was conducted, including species, species coverage, and modular traits of some species in different seasons.

Results of the survey compiled in 2011 revealed that there were 54 species of 25 families, 49 species of 18 families, and 45 species of 20 families of weed in the three sites. Different soil and environmental conditions had different weed species with different dominant species. For example, in Fujian, dominant species were Biden pilosa, Erigeron annuus, Imperata cylindrical, and Rublaceae cordifolia, while in Honghu, dominant species were Humulus scandens, Setaria faberii, Glycine soja, Artemisia annua, and Artemisia princeps, and in Yichang, dominant species were Cynodon dactylon, Erigeron annuus, Lindernia ciliate, Setaria faberii, and Bidens pilosa. *Hubei-34*

Balanced Nutrient Management for Maximizing Rapeseed Yield in China

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Project Cooperators: Jiang Cun-cang and Li Xiao-kun

In 2011, the IPNI China Program in collaboration with Huazhong Agricultural University conducted a total of 40 rapeseed fertilization field trials in the main rapeseed production provinces such as Hubei, Hunan, and Jiangsu with similar treatments in rice-rapeseed and cotton-rapeseed rotations. The treatments included: 1) NPKB (N 180 kg/ha, P_2O_5 70 kg/ha, K_2O 100 kg/ha, Borax 7.5 kg/ha); 2) PKB; 3) NKB; 4) NPB; and 5) CK (no fertilization).

Results from the trials showed that, in farms with rice-rapeseed rotation, the best average seed yield (2,508 kg/ha) was obtained with NPKB treatment. This treatment increased yields by 91, 25, 16, and 123% over PKB, NKB, NPB and CK treatments, respectively. In farms with cotton-rapeseed rotation, the best average seed yield (2,624 kg/ha) was again obtained with NPKB treatment, which increased yields by 56, 29, 23, and 86% over PKB, NKB, NPB and CK treatments respectively. Yield response to N fertilization in rice-rapeseed rotation was better than that in cotton-rapeseed rotation, but the response of K fertilization was opposite, and P fertilization showed a significant difference between the two systems. *Hubei-35*

Ecological Effect and the Utilization Rate of Potassium for Different Potassium Efficiency Cotton Genotypes

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To identify genotypes with higher K efficiency and understand the mechanism of differences in response to K deficiency among genotypes, a pot culture experiment was conducted in the greenhouse of the College of Resources and Environment of Huazhong Agricultural University from May 7 to October 15, 2011. Study on the effect of dry matter and K distribution and accumulation between 2 different cotton genotypes (high and low K-use efficiency) was conducted with grafting technology.

Results showed that the effect of grafting on dry matter and K accumulation, distribution and yield was different between the two cotton genotypes under different K conditions. After grafting, the ratio of dry matter and K accumulation in the vegetative organ of high K-efficiency cotton genotype was increased, but the same decreased in the reproductive organs. Moreover, yield and K utilization index also decreased. On the contrary, the condition of low K-use efficiency cotton genotype gave an opposite effect. After grafting, the K uptake efficiency of high K-use efficiency cotton genotype decreased with applied K and increased without applied K. However, low K-use efficiency cotton genotypes reversed this trend, and their K uptake efficiency increased with K application and decreased with no K application after grafting. In summary, we conclude that the effect of grafting on different cotton genotypes was different. *Hubei-37*

Nutrient Transfer among Plant, Soil, and Environment in the Typical Cropping Systems of Hubei Province

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Nutrients are lost through runoff, leaching, and harvest, and at the same time increased through fertilization, rainfall, irrigation, and straw return in the main cropping systems of Hubei province. These phenomenon were studied by the Soil and Fertilizer Institute of Hubei in 2011.

Results from the 20 field experiments showed that nutrient loss in farmland through irrigation was mainly of K, followed by N. Phosphorus loss through irrigation was very low. Soil nutrients from atmospheric deposition mainly included N (11 to 47 kg/ha and 80% of this was NO_3^-), followed by K (6.5 to 76.6 kg/ha, water-solubility K) and P (0.2 to 3.7 kg/ha, particulate P). The runoff water lost from the experimental sites was 65 to 729 mm. The ratio of the amount of runoff water to the amount of rainfall was 0.22. The average runoff amounts of total N, total P, and water-soluble K were 14.6, 1.5, and 24.6 kg/ha, respectively. These values showed a positive correlation with the amount of runoff water, rather than with the rates of N, P, and K application. *Hubei-38*

Study on High Efficiency Nutrient Use and Regulation of Soil Nutrient Dynamics for High Yields of Rice

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Project Cooperators: Nie Jun and Liao Yulin

Rice crop plays a crucial role in food production of China. Hunan is the largest rice production province in China with an annual production of 29.1 M t. To study high efficiency nutrient use and regulate soil nutrient dynamics for increasing rice yields, Hunan Institute of Soil and Fertilizer collected in 2011 a total of 24 samples from eight main double-rice production counties.

Results showed that the amounts of bacterium, fungi, and actinomycetes and the contents of soil microbial biomass carbon (SMBC) and soil microbial biomass N (SMBN) in both high and medium productive paddy soils did not differ significantly. Similarly, the observed trends in activities of urease, phosphatase, invertase, dehydrogenase in both high and medium productive paddy soils showed no significant difference. Double rice planting areas in Hunan, with a history of applying P fertilizer for the last 50 years at least leading to high soil P levels, resulted in no significant differences in phosphatase activity in high, medium, and low productive paddy soils. Correlation analysis showed that soil bacterium and actinomycetes had the best correlation with soil organic carbon (SOC), total N (TN), total K, and available N (AN). Soil urease and invertase activities had the best correlation with SOC, SMBC, SMBN, TN, AN. Most of the microbiological and biochemical indicators did not differ significantly between high and medium productive paddy soils, but differed significantly from the low productive paddy soil. Therefore, low productive paddy soil should get more attention in terms of balanced application of organic manures and inorganic fertilizers. High productive paddy soil in double-rice cropping regions of Hunan showed 48±12 g/kg of organic matter content, 2.7±0.7 g/kg of TN, 40±14 mg/kg of available P, and 106±23 mg/kg of available K. Textures of high productive paddy soils were generally loamy and sandy clay loam with weak K retention capacity. Therefore, since the available of K content was not high in highly productive paddy soils, these soils would benefit from an application of K fertilizer. *Hunan-16*

Effect of Rice Straw Return on Paddy Organic Content and Heavy Metal Availability

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A long-term field experiment with early rice-late rice-winter fallow cropping system has been in place in Wangcheng county since 1981. The treatments include CK (without fertilization), NP, NK, NPK, NK+Pig manure (PM), NP+rice straw (RS), and NPK+RS.

Thirty-year average annual grain yield showed the following trend among treatments: control < NK < NP < NK+PM < NP+RS < NPK < NPK+RS treatments. NPK treatment increased grain yield by 56.7 kg/ha per year over NP treatment. A positive, linear correlation was observed between the soil organic matter accumulation and the duration of the experiment in the NK treatment, while a negative, linear correlation was observed in CK and NP treatments. There were significant differences in different treatments for soil organic carbon (SOC), easily oxidizable organic carbon (EOC), microbial biomass carbon (MBC), light fraction organic carbon (LFOC), humic acid organic carbon (HA-C) and fulvic acid organic carbon (HF-C) in the plow layer of reddish paddy soils after 54 growing seasons. SOC, EOC, MBC, LFOC, HA-C and HF-C were significantly higher in treatments with combined application of organic manures and inorganic fertilizers than with the application of inorganic fertilizers (NP, NK and NPK) alone. The proportion of active organic C to SOC was MBC<LFOC<EOC. SOC was positively related to EOC and LFOC.

At the beginning of the field experiment, the total contents of soil heavy metals As, Cr, Cu, Ni, Zn, Pb, Cd, and Co were 33, 93, 40, 28, 51, 43, 0.3, and 5 mg/kg. After 30 years of rice straw return to the field, the same heavy metal contents increased in the NP treatment to 36 (8.29%), 96 (3.28%), 41 (3.42%), 34 (20.6%), 65 (25.7%), 65 (51.4%), 0.4 (48.3%), and 6 (20.4%) mg/kg, respectively, and to 34 (9.75%), 110 (3.49%), 45 (8.44%), 34 (1.2%), 68 (16.3%), 62 (37.6%), 0.4 (22.2%), and 5 (9.49%) mg/kg, respectively in the NPK treatment. *Hunan-17*

Research on Balanced Fertilization Technology of Sweet Potato

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Project Cooperators: Wang Jidong, Ning Yunwang, and Zhang Hui

This project aimed to increase sweet potato yield and quality through optimum fertilization, and establish the soil nutrient classification indexes and demonstrate balanced fertilization technology for sweet potato. Field trials were carried out in Guanyun county and Liuhe district of Nanjing, Jiangsu province by Jiangsu and Hubei Academy of Agricultural Science in 2011.

Results from Hubei and Jiangsu showed that the highest dry matter yield (13,905 kg/ha) and best net profit were obtained with applications of 135 kg N/ha and 160 kg P_2O_5/ha. However, in Hubei, the highest dry matter yield (9,600 kg/ha) and best net profit were obtained with applications of 165 kg N/ha and 248 kg P_2O_5/ha. The results emphasized the need for developing site-specific fertilizer recommendations for a crop. *Jiangsu-11*

Technologies for High Efficient Fertilization and Reduction of Non-point Source Pollution in Jiangxi

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Project Cooperators: Fusheng Yuan, Zuzhang Li, Qixiang Luo, Gang Sun, Changxu Xu, Duogen Xiong, and Wenxue Zhang

Apart from industrial pollution, non-point source pollution is another high priority concern in agricultural production. Over application of fertilizers and pesticides not only degrades the environmental quality, but also increases the cost of production. Therefore, a study on the non-point source pollution is important for making policies, rules, and management systems. Field experiments with rice crop were carried out in 2011 by the Soil and Fertilizer Institute, Jiangxi Academy of Agricultural Sciences to study fertilizer-saving, pollution-reducing, and efficiency-improving agricultural production technology and its contribution to non-point source pollution in Nanchang county. Treatments included: (1) NPK, (2) -25% NP, (3) -50% NP, (4) -25% N + -50% P, (5) -50% N + -25% P, (6) OM (organic manure), (7) 50% OM + 50% CF (chemical fertilizer), and (8) CK (no fertilization). In treatment 1, 150 kg N/ha, 75 kg P_2O_5 /ha, and 150 kg K_2O/ha were applied to early rice and 180 kg N/ha, 60 kg P_2O_5/ha, and 180 kg K_2O/ha to late rice. Nitrogen and K were applied as 50% basal, 30% was top dressed at tillering stage, and 20% top dressed at heading, while all P was applied basal.

Results showed that applying NPK or 50% OM + 50% NPK gave similar early and late rice yields. This implied that temporarily and properly reduced chemical fertilizer rates did not affect rice yields. To start with the adoption of improved production technology, and based on farmers'common practice, we recommend reducing N and P fertilizer rates by 25% to get same rice yield but with decreased risk of non-point source pollution. Additional application of organic manure can significantly decrease the amounts of N and P loss in run-off. *Jiangxi-26*

Efficient Nutrient Management For Forage Grasses and Animal Product Quality

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In the world's domestic animal industry, fodder and grain-saving domestic animals account for more than 90%, while the grain-consuming domestic animals only account for less than 10%. However in China's domestic animal industry, these two types of domestic animals account for 42% and 58%, respectively. Therefore, developing the cultivation industry of herbivore domestic animals is an efficient practice for keeping food security and sustainable agriculture. Herbivore domestic animals belong to grain-saving animal category, so the cultivation cost and the negative effects on the environment are relatively low. There are over 1 M ha of winter fallow lands in Jiangxi that can be used for feeding the herbivore domestic animals. A field experiment with Italian ryegrass under Mexico maize-Italian ryegrass cropping system was conducted in 2011 in Nanchang county of Jiangxi by the Soil and Fertilizer Institute, Jiangxi Academy of Agricultural Sciences, to evaluate the effect of balanced nutrition management on yield of fodder crops and animal quality.

Results showed that Italian ryegrass significantly enhanced cow milk production by 84 to 88% compared with other grasses. The yield of Italian ryegrass with application of (kg/ha): 500 N, 288 P_2O_5, 540 K_2O,

652 Ca, 7 Mg, 7 Zn, and 0.2 Se was increased by 8.2 t/ha and profit by 12% over the NPK treatment. Also, this yield was 131, 43, and 42% higher than the yields in minus N, P and K treatments, respectively. Zinc and Se contents of Italian ryegrass increased by 7 and 50% respectively. There was some effect of different treatments on goose meat quality. Additional application of Zn and Se enhanced their contents in meat by 11 and 60%, and increased P, Mg, and amino acid contents by 8, 9, and 16, respectively. Straw from Italian ryegrass when returned to the farmland at 6,413 kg/ha increased the yield of early rice by 1,067 kg/ha than with no straw returned. *Jiangxi-27*

Efficient Nutrient Management Strategy for Modern Rice Planting in China

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Rice is the most important grain crop in China. Large amounts of commercial fertilizers are used annually for higher rice production, but with low use efficiency. To establish better nutrient management strategies for rice in different regions of China, the IPNI China program in collaboration with Soil and Fertilizer Institute of Jiangxi Academy of Agricultural Science, a nationwide cooperative research project was carried out in 11 main rice production provinces (Jiangxi, Hunan, Guangxi, Fujian, Zhejiang, Jiangsu, Anhui, Hubei, Sichuan, and Yunnan). A total of 37 on-farm rice fertilization trials were conducted in the 11 provinces in 2011 with different cropping rotations and soil fertility levels.

Results indicated that, in all regions, optimal fertilizer treatment (OPT; NPKZn) obtained higher rice yields compared with the no fertilizer (CK) treatment (22% to 70%) and common farmer practices (12%). Nitrogen was the most important nutrient limiting factor for rice, followed by P, K, and Zn. The optimum N fertilization rates for late rice and mid-season rice were 180 and 240 kg/ha, respectively. Based on the results, an optimum N application strategy was suggested that included the application of 40% of N fertilizer as basal, and then top dressing 20% of N fertilizer each at tillering, panicle initiation, and spike growth stages of rice. *Jiangxi-30*

Transformation, Interaction and Bioavailability of Nutrients in the Fertisphere

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In the interface of soil and fertilizer, the concentration of nutrients is several times that in bulk soil, resulting in strong and special reactions between nutrients or nutrients and soil fractions. It's important to study the transformation, transference, and reactions of nutrients in this micro-zone to better understand their effect on the enhancement of fertilizer use efficiency and in designing new fertilizer products. Study on the effects of interactions of N and K, or N and P, and the application sites on K or P use efficiency, could help design better fertilization strategies and enhance K and P use efficiencies. The effects of ammonium and K interaction on the transformation and transference of K in the paddy soil-fertilizer interface were studied in 2011 by the Nanjing Institute of Soil Science, CAS. In addition, the effects of N and P interaction on the transformation and transference of P, and the influence of N and P fertilization on the uptake and bioavailability of N and P on wheat in the alluvial soil were also explored.

The use efficiency of K fertilizers could be increased by reducing the fixation of K in soil fertisphere. When potash was applied together with ammonium, the contents of soil water soluble and exchangeable K were increased in the paddy soil fertisphere, while the non-exchangeable K content was decreased. The increase of water soluble P and Ca_2-P contents and the decrease of Ca_8-P content was found in the co-application of $Ca(H_2PO_4)_2$ and $(NH_4)_2SO_4$ treatment. But when $Ca(H_2PO_4)_2$ was co-applied with urea, these effects of N fertilizers on the P availability of co-applied P fertilizer were not expressed in the wheat pot experiment. Maximum N use efficiency was observed when N was applied 5 cm below wheat roots in the soil. When P fertilizer was mixed thoroughly with soil near roots, the best P use efficiency was obtained. *Nanjing-11*

Improving the Method and Classification System for Evaluating Soil Available Potassium and Plant Potassium Status for Rice and Winter Wheat in Nanjing

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Scarce and imbalanced application of K in China has resulted in a widespread exhaustion of K reserves in cropland soils during recent decades. The most common soil K fertility index used is soil available K, measured using the 1 mol/L ammonium acetate (NH_4OAc) method. However, this method was only suitable for evaluating K availability in soils of the same type or with similar K buffering capacity, but not in soils with variable K buffering capacity, or in soils where the non-exchangeable K contribution to plant K uptake varies. So, establishing a better method to accurately determine plant available K in various soils and the precise diagnostic indexes of plant K and a stable uniform fertilizer recommendation index are important for improving K utilization efficiency. The Nanjing Institute of Soil Science, Chinese Academy of Sciences, conducted in 2011 a rice pot culture experiment with 12 soils differing in K fertility and K buffering capacity. During the whole growing period, different tissues of rice plants were sampled according to the growing stages. The tissue K content was measured and compared among different organs and different growth stages. The relationship between tissue K content and soil K availability indicated by various methods was analyzed to find which method would best define the plant available K in the soil.

Result showed that the first leaf (counting from top) K content at tillering stage, the third leaf K at elongation stage, and the K content of the third leaf including the sheath at full heading stage could be used as diagnostic indices of rice K nutrition. Potassium contents of 3.46, 1.77, and 1.00% in the diagnostic organs at the three growing stages could be used as the indices of rice K supply status. Both sodium tetraphenyl boron ($NaBPh_4$) method (0.2 mol/L, 30 min) and cold HNO_3 extraction method (0.5mol/L, 8 h) are good for evaluating rice soil K availability. Based on the mathematical function obtained via the relationship between soil available K content and relative yield of rice, taking relative yield of 90% as the critical point, the critical values for soil available K were 330 and 144 mg/kg for $NaBPh_4$ and HNO_3 methods, respectively. *Nanjing-12*

Fertilization Recommendation Technique for Vegetable Greenhouse in Shanghai Suburbs

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Protected (greenhouse) vegetable land has developed quickly in recent year in Shanghai suburbs to increase farm productivity. According to 2010 statistics, including 9 districts and Chongming county and Guangming Food Corporation, Shanghai already has more than 13,501 ha of horticultural facilities (greenhouse). However, many problems such as secondary salinization, acidification in vegetable greenhouse soil have become more and more serious. About 30% of the greenhouses soils have suffered stress of secondary salinization. Soil secondary salinization is the main reason for limiting vegetable production in greenhouse in Shanghai suburbs. In order to study the influence of soil salinity on vegetable, greenhouse pot experiments were conducted in 2011 by the Soil and Fertilizer Institute, Shanghai academy of agricultural Sciences. Hoagland nutrition liquid was used in these experiments as nutrient resource.

Results indicated that excessive fertilization resulted in salinization, which inhibited and harmed the growth of the vegetables. The damage of soil secondary salinization to vegetable mainly occurs at the seedling stage with germination rate and/or survival rate of seedling. Under normal circumstances, the threshold limit at which soil salinity can harm vegetable seedling was found out to be 3.0 g/kg. Vegetable seedlings would be seriously harmed when the content of soil salinity reached 6.0 g/kg. *Shanghai-09*

Environmental Factors Affecting Uptake and Utilization of Nitrogen and Phosphorus by Vegetable Crops

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Project Cooperators: Zhang Yong-song and Zhang Qichun

The intensive vegetable cultivation using high fertilizer input were selected to study the effects of environmental factors on transformation, uptake, and utilization of N and P in soils. The objective of the study was to provide a theoretical basis and technical support for improving fertilizer use efficiency. Soil water contents in the incubation experiments were kept constant in this study. Two greenhouse vegetable soils were used. The soils had different soil N mineralization microbial communities—difference in community

compositions induced by soil type was greater than those induced by soil moisture changes. Multivariate analysis of community-level physiological profile and phospholipid fatty acid data indicated that soil moisture regime had a significant effect on soil microbial community substrate utilization pattern and microbial community composition. Hydroponic experiments were carried out to investigate the effects of three ratios of nitrate to ammonium (75/25, 50/50, 25/75) on biomass, photosynthetic system, and antioxidant defense systems with Chinese cabbage grown under different light (full light, 15% full light) and moisture (0% PEG, 2.5% PEG) conditions.

Plant growth and photosynthetic ratio were greatly inhibited under conditions of shade (15% full light) and water stress (2.5% PEG), whereas appropriate NO_3^-/NH_4^+ ratio (75/25) could improve shoot growth and root growth and activities, and enhance the photosynthetic intensity. Under shading (15% full light) and water stress (2.5% PEG), higher contents of ROS (H_2O_2, O_2^-), and MDA, and lower contents of antioxidants and activities of antioxidative enzymes were observed in the low and high N treatments. In combined stresses of shading and water stress, the lower ROS and MDA contents, and higher biomass, root growth, antioxidant (AsA, GSH) contents, antioxidative enzyme (POD, APX and GR) activities and the total antioxidant capacity evaluated as the 2, 2-diphenyl-1-picrylhydrazyl-radical scavenging activity and the ferric reducing/ antioxidant power in cabbage seedlings were found at NO^3-/NH_4^+ ratio (75/25) in the nutrient solution. These results suggest that appropriate NO_3^-/NH_4^+ ratio (75/25) in the nutrient solution could improve plant growth by enhancing the antioxidant defense capacity, which prevents ROS accumulation under adverse environmental conditions. *Zhejiang-25* ❖

Asia and Africa Group

China

Northwest Region: Dr. Shutian Li

Nutrient Management and Balanced Fertilization in Ningxia

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Project Cooperators: Fang Wang and Tiancheng Zhao

Two experiments were conducted in 2011 in Ningxia province to: (a) investigate limiting nutrients for maximum rice yields by comparing the yields in optimal treatment (OPT) with yields obtained in nutrient omission plots; and (b) determine the optimal K rate for cabbage.

An OPT trial in rice was conducted in Lingwu city. Results showed that the average yield with recommended OPT (225-90-75 kg N-P_2O_5-K_2O/ha) was 10,292 kg/ha, which was 141%, 4%, and 2% more than that obtained plots omitting N, P, and K, respectively. This indicated N as the main limiting factor in rice production in Ningxia, while P and K were found to be sufficient.

A potash rate trial in cabbage in Lingwu showed that increasing K rates increased cabbage yield by 13.1% to 20.8%. The highest cabbage yield was obtained with 300-150-225 kg N-P_2O_5-K_2O/ha treatment. Increasing K rates to 300 kg K_2O/ha reduced cabbage yield by 6.7%. However, there was no statistically significant yield difference between 225 and 150 kg K_2O/ha treatments. Economic analysis showed that the highest income (USD 300/ha) was obtained in 150 kg K_2O/ha treatment, which incidentally also had higher K recovery efficiency of all K treatments. In summary, the appropriate rate of K in cabbage in Lingwu, Ningxia, was found to be 150 kg K_2O/ha. *Ningxia-NMBF*

Nutrient Management and Balanced Fertilization in Inner Mongolia

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Project Cooperators: Yu Duan, Peiyi Zhao, and Huanchun Li

Field trials were conducted on irrigated/rainfed potato, sunflower, and maize to demonstrate: (1) yield responses to balanced fertilization, and (2) effect of nutrient management under rain collecting or irrigation on crop yield and nutrient use efficiency.

In flood irrigated potato in Wuchuan County, application of 240-90-165 kg N-P_2O_5-K_2O/ha produced 44.3 t/ha, which was 16%, 14%, and 12% more than the yields in N, P, and K omission plots, respectively. A rainfed potato trial produced 18.9 t/ha with 150-60-75 kg N-P_2O_5-K_2O/ha, which was 22%, 30%, and 20% more than the yields in N, P, and K omission plots. Nitrogen and K recovery efficiencies under irrigation were 50% and 65%, while in rainfed conditions, these were lower at 22% and 39%, respectively. A study on rainfed potato at the Wuchuan Experimental Station found that plastic mulch coverage for collecting rainfall could produce 25% more tuber yield, and 9.9, 5.0, and 22% higher N, P, and K recovery efficiencies, respectively, as compared to no plastic mulch coverage.

Sunflower experiments in Wuyuan County demonstrated highest seed yields under the optimum (OPT) treatment of 225-75-135 kg N-P_2O_5-K_2O/ha. Agronomic efficiencies were 2.7 kg seed/kg N, 5.5 kg seed/kg P_2O_5, and 2.0 kg seed/kg K_2O, and the average recovery efficiencies for N, P, and K fertilizer were 26.7, 17, and 54%, respectively. Compared with farmer practice (225-225-0 N-P_2O_5-K_2O/ha), OPT produced 12.7% more seed yield and USD 494 more profit.

Results from a sprinkler-irrigated maize trial at Dalate County, Erdos, revealed that application of 270-120-180 kg N-P_2O_5-K_2O/ha produced 39, 36, and 54% more grain yields than the N, P, and K omission plots. Application rates of N, P_2O_5 and K_2O for optimum economic yield were 238, 114, and 128 kg/ha, respectively. Accumulation of biomass and nutrient uptake in plastic mulch covered potato, sunflower, and sprinkler irrigated maize were also evaluated for future consideration regarding nutrient management in these crops. *Inner Mongolia-NMBF*

Effect of Long-term Application of Potash and Straw Return on Wheat Yield and Soil Potassium Balance in Qinghai Province

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This fixed-site, irrigated spring wheat experiment is on a loamy, Chestnut soil site in northeastern Xining City of Qinghai Province since 1993. The study is evaluating the long-term agronomic effects of NP and NPK treatments used in combination with complete, 50%, and zero straw recycling.

In 2011, after 19 years of study, wheat yield of NP treatment was 5.9% lower than that of NPK treatment. Use of NP plus 50% or 100% straw recycling were as productive as the NPK treatment. Straw recycling with fertilizer K generated similar yield to straw recycling without fertilizer K. The K balance in the NP treatment was -139 kg/ha, while in the NPK treatment, it was -21 kg/ha. Partial and complete straw recycling without fertilizer K application generated a soil K deficit of -84 kg/ha and -14 kg/ha, respectively. Only the NPK plus straw return could maintain a positive soil K balance and soil K surplus. Testing of soil physical properties indicated that straw returning decreased soil bulk density and increased soil moisture content. *Qinghai-2011*

Nutrient Management and Balanced Fertilization for Major Crops in Shaanxi

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Project Cooperators: Yimin Gao, Shulan Zhang, and Ruliang Liu

Experiments in 2011 focused on water and nutrient interaction in apple and NPK application ratio in kiwi in Shaanxi Province. The nutrient and water interaction research was conducted in a 9-year-old Fuji apple orchard (1,667 trees/ha) at Fengxiang County and a 5-year-old Fuji apple orchard (1,667 trees/ha) at Pucheng County.

At the nutrient recommendation of 0.6-0.24-0.3 kg N-P_2O_5-K_2O/tree, drip fertigation at four growing stages (viz., 20% at basal, 30% at bud emergence in the spring, 50% at fruit expending [30% on Jun 10, 20% on July 20]) produced 14% and 8% more fruit yield in Fengxiang and Pucheng counties, respectively than the same amount of nutrients applied in soil at four stages, but with flood irrigation. Half of the recommended nutrients plus the drip fertigation produced similar or more fruit yield to the fully recommended nutrients applied with flood irrigation. Economic analysis indicated that fertigation resulted in USD 7,089/ha more income in Fengxiang County and USD 2,160/ha more income in Pucheng county than flood irrigation practice.

Research on NPK ratio in Kiwi in Yangling City determined 0.23-0.12-0.12 kg N-P_2O_5-K_2O/tree (2,000 trees/ha) to be the optimal fertilization dose. This dose produced 47.7 t/ha of kiwi fruit—12, 12, and 26% more than the 1/2N, 1/2P, and 1/2K treatments, respectively. These yield gaps produced more value for the optimal dose by USD 3,861, 4,019, and 7,604/ha, respectively. Evaluation of an additional treatment supplying 50% more NPK resulted in similar yield to NPK. The NPK recommendation plus 8 kg farmyard manure generated 3% more yield over NPK alone, and increase profits by USD 1,007/ha. *Shaanxi-NMBF*

Nutrient Management of Cotton and Processing Tomato with Drip Irrigation in Xinjiang Province

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Agriculture in Xinjiang is water dependent, and more than 90% of crops here are irrigated. Drip irrigation continues to be most popular in crops such as cotton and processing tomato. The study in 2011 mainly focused on balanced fertilization and P management in cotton and processing tomato.

In the drip-irrigated cotton grown in Changji City, the recommended NPK rate of 240-150-75 kg N-P_2O_5-K_2O/ha and its corresponding omission plots found N to be most limiting followed by P and then K. Agronomic efficiencies (AE) at the recommendation fertilizer rate were 7 kg seed cotton increase/kg N, 7 kg seed cotton increase/kg P_2O_5, and 54 kg seed cotton increase/kg K_2O, while recovery efficiencies (RE) were 56, 25, and 58%, respectively. Basal application of 65% of the recommended P rate before planting and the remaining 35% applied through drip irrigation produced 6% more yield than 100% basal application, and also improved P use efficiency. Fertigation with reduced P rate (2/3 recommended P) produced 5% more yield than 100% recommended P as basal application.

In drip-irrigated processing tomatoes grown in Changji City, the recommended NPK rate of 360-210-120 kg N-P_2O_5-K_2O/ha increased tomato yields by 567, 16, and 5% when compared with yields in -N, -P and -K plots, respectively. Agronomic efficiencies at the recommended fertilizer rate 77 kg tomato/kg N, 49 kg tomato/kg P_2O_5, and 32 kg tomato/kg K_2O, while RE were 48, 25, and 54%, respectively. Application of P with fertigation produced similar tomato yields as with 100% basal application. *Shaanxi-NMBF* ❖

Asia and Africa Group

China

Northcentral Region: Dr. Ping He

Nutrient Expert-based Fertilizer Recommendations for Winter Wheat in Hebei

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Project Cooperators: Chuanjie Li, Suli Xing, and Baowen Han

This study was conducted to validate Nutrient Expert (NE)-based fertilizer recommendations for winter wheat in farmer fields and compare them with farmer fertilizer practice (FFP). For this, thirty two (32) on-farm experiments were conducted in four different counties in Xinji, Hebei Province. NE-based fertilizer recommendation plots received on average 135-52-60 kg N-P_2O_5-K_2O/ha, respectively, while farmer fertilizer practice (FFP) plots received an average of 278-42-24 kg N-P_2O_5-K_2O/ha, respectively.

First year results of the study showed that although grain yields in NE (7.6 t/ha) and FFP (7.4 t/ha) treatments were statistically similar, the profit obtained was higher in NE (USD 2,439/ha) when compared with FFP (USD 2,281/ha). Moreover, significantly higher agronomic efficiency of N (8.8 kg/kg), N recovery efficiency (29.4%), and partial factor productivity (56.8 kg/kg) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 3.2 kg/kg, 14.2%, and 27 kg/kg. The study demonstrated that NE was an effective fertilizer recommendation method in Hebei. *Hebei-NMBF*

Nutrient Expert-based Fertilizer Recommendations for Winter Wheat and Spring Maize in Shanxi

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Project Cooperator: Bin Wang

This study was conducted to validate Nutrient Expert (NE)-based fertilizer recommendations for winter wheat and spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, 11 on-farm experiments were conducted in Linfen, Shanxi province. NE-based fertilizer recommendation plots received on average 137-67-78 kg N-P_2O_5-K_2O/ha for wheat and 172-46-58 kg N-P_2O_5-K_2O/ha for maize, respectively, while farmer fertilizer practice (FFP) plots received an average of 262-110-28 kg N-P_2O_5-K_2O/ha for wheat and 244-26-18 kg N-P_2O_5-K_2O/ha for maize, respectively.

First year results of the study showed that grain yields and profits in NE (8.3 t/ha and USD 2,773/ha for wheat and 9.7 t/ha and USD 3,284/ha for maize, respectively) and FFP (8.6 t/ha and USD 2,789/ha for wheat and 9.5 t/ha and USD 3,236/ha for maize, respectively) treatments were statistically similar. However, significantly higher agronomic efficiency of N (11.3 kg/kg for wheat and 7.2 kg/kg for maize), N recovery efficiency (37.3% for wheat and 25.7%% for maize), and partial factor productivity (63.9 kg/kg for wheat and 56.5 kg/kg for maize) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 7.4 kg/kg and 5.4 kg/kg, 26.6% and 17.9%, and 36.6 kg/kg and 44.3 kg/kg for wheat and maize, respectively. With NE, 47.7% and 29.5% less fertilizer N was used than that used in FFP for wheat and maize, respectively. The study demonstrated that NE was an effective fertilizer recommendation method in Shanxi. *Shanxi-NMBF*

Nutrient Expert-based Fertilizer Recommendations for Winter Wheat and Spring Maize in Henan

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Project Cooperator: Bingqi Li

This study was conducted to validate Nutrient Expert (NE)-based fertilizer recommendations for winter wheat and spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, thirty (30) on-farm experiments were conducted for wheat and 12 for maize in Zhumadian, Henan province. NE-based fertilizer recommendation plots received on average 154-78-79 kg N-P_2O_5-K_2O/ha for wheat and 150-50-62 kg N-P_2O_5-K_2O/ha for maize, respectively, while farmer fertilizer practice (FFP) plots received an average of 249-119-119 kg N-P_2O_5-K_2O/ha for wheat and 206-15-15 kg N-P_2O_5-K_2O/ha for maize, respectively.

First year results of the study showed that grain yields and profits in NE were both higher than those in FFP treatments. However, significantly higher agronomic efficiency of N (16.6 kg/kg for wheat and 18.4 kg/kg for maize), N recovery efficiency (52.9% for wheat and 43.0% for maize), and partial factor productivity (52.0 kg/kg for wheat and 53.0 kg/kg for maize) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding FFP values were 9.7 kg/kg and 12.7 kg/kg, 18.6% and 25.2%, and 31.5 kg/kg and 38 kg/kg for wheat and maize, respectively. With NE, 38.2% and 25.2% less fertilizer N was used than that used in FFP for wheat and maize, respectively. The study demonstrated that NE was an effective fertilizer recommendation method in Henan. *Henan-NMBF*

Global Maize Project in China: Dahe, Shijiazhuang, Hebei Province

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Project Cooperator: Chunjie Li

This long-term experiment was initiated in June 2009 in Hebei province. Summer maize was the first crop grown at this site, where winter wheat-summer maize rotation system is common. The main plot had two treatments: a) ecological intensification (EI) treatment with 120-60-80 kg N-P_2O_5-K_2O/ha fertilizer application in winter wheat and 150-40-50 kg N-P_2O_5-K_2O/ha in summer maize; and b) farmer practice (FP) treatment with 225-120-50 kg N-P_2O_5-K_2O/ha fertilizer application in winter wheat and 300-135-0 kg N-P_2O_5-K_2O/ha in summer maize. Three subplots included: a) N applied in all 3 years (N all yr), b) N applied in 2 of every 3 years (N 2/3 yr), and c) no N applied (N 0 yr). Winter wheat was planted on October 19, 2010 and harvested on June 18, 2011, while summer maize (storage maize) was planted in the same plots on August 20, 2011 and harvested on October 12, 2011.

No significant difference in grain yields was found between EI and FP treatments for winter wheat, although higher N and P were applied in FP. However, agronomic N efficiency (kg grain yield increase per kg N applied) was higher in the EI treatment (13.3 kg/kg) than in the FP treatment (9.4 kg/kg). Similarly, partial factor productivity of N (kg grain yield per kg N applied) was considerably higher in the EI treatment (67.3 kg/kg) than in the FP treatment (37.7 kg/kg). Similar trends for grain yield and N use efficiencies were found in summer maize. N 2/3 yr treatment produced yields similar to N all yr treatment. This demonstrated that skipping N application in two seasons did not affect the grain yield during the third maize growing season. *IPNI-21* ❖

Asia and Africa Group

China

Northeast Region: Dr. Ji-yun Jin, Director, China Program

Nutrient Expert-based Fertilizer Recommendations for Spring Maize in Heilongjiang

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Project Cooperator: Shuangquan Liu

Nutrient Expert (NE) is a new, computer-based decision support tool developed to assist local experts to formulate fertilizer guidelines for maize (corn) in real-time, and is based on the principles of site-specific nutrient management (SSNM). This tool comes in handy, especially when soil testing facilities are not easily accessible, which makes timely fertilizer recommendations difficult. This study was conducted to validate NE-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, twenty six (26) on-farm experiments were conducted in four different counties in Heilongjiang province. NE-based fertilizer recommendation plots received 156 kg N, 57 kg P_2O_5, and 75 kg K_2O/ha, on average, while farmer fertilizer practice (FFP) plots received an average of 185 kg N, 66 kg P_2O_5, 51 kg K_2O.

Grain yield (8.4 t/ha) and profit (USD 1,735/ha) were higher in NE-based treatments than in the FFP, where corresponding values were 8.2 t/ha and USD 1,667/ha. Also, higher agronomic (14.5 kg/kg) and recovery (32.3%) efficiencies of N were obtained using NE-based fertilizer recommendations than using FFP, where corresponding values were 11.2 kg/kg and 26.6%. The NE-based treatment used 15.7% less fertilizer N than that used in the FFP. Thus, the first year results of this study showed a good promise for NE-based fertilizer recommendations to extend to farmers. *Heilongjiang-NMBF*

Nutrient Expert-based Fertilizer Recommendations for Spring Maize in Liaoning

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Project Cooperator: Yuehua Xing

This study was conducted to validate Nutrient Expert (NE)-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, twenty four (24) on-farm experiments were conducted in four different counties in Liaoning province. NE-based fertilizer recommendation plots received on average 194-59-69 kg N-P_2O_5-K_2O/ha, respectively, while farmer fertilizer practice (FFP) plots received an average of 222-75-48 kg N-P_2O_5-K_2O/ha, respectively.

First year results of the study showed that although grain yields in NE and FFP treatments were statistically similar, the profit obtained was USD 255/ha higher in NE. Moreover, significantly higher agronomic efficiency of N (9.9 kg/kg) and partial factor productivity (56 kg/kg) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 5.5 and 46 kg/kg. The study demonstrated that NE was an effective fertilizer recommendation method in Liaoning. *Liaoning-NMBF*

Nutrient Expert-based Fertilizer Recommendations for Spring Maize in Jilin

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Project Cooperators: Jiagui Xie and Xiufang Wang

This study was conducted to validate Nutrient Expert (NE)-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, thirty (30) on-farm experiments were conducted in five different villages in Gongzhuling city, Jilin province. NE-based fertilizer

recommendation plots received on average 150-57-58-20-5 kg N-P_2O_5-K_2O-S-Zn/ha, respectively, while farmer fertilizer practice (FFP) plots received an average of 202-107-91 kg N-P_2O_5-K_2O/ha, respectively.

First year results of the study showed that grain yield (12.1 t/ha) and profit (USD 3,452/ha) obtained in NE-based treatments were higher than those in the FFP, where corresponding values were 11.9 t/ha and USD 3,294/ha although not statistically significant. However, significantly higher agronomic efficiency of N (18.8 kg/kg) was obtained using NE-based fertilizer recommendations than using FFP, where the corresponding value was 13.1. Also, 25.7% less fertilizer N was used in the NE-based treatment than that used in the FFP. Thus, the first year results of this study demonstrated the promise of NE tool as a viable alternative to soil testing. *Jilin-NMBF*

Global Maize Project in China: Liufangzi, Gongzhuling, Jilin Province

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Project Cooperators: Jiagui Xie and Xiufang Wang

This long-term field experiment was initiated in 2009 in Liufangzi, Gongzhuling City, Jilin Province, where mono-cropping of spring maize is common. The aim of the experiment is to compare the performance of ecological intensification (EI) practices with common farmers' practice (FP) for yield and N use efficiencies. The main plot had two treatments: (a) EI treatment with 180-75-90-20-5 kg N-P_2O_5-K_2O-S-Zn/ha fertilizer application and (b) a FP treatment with 251-145-100 kg N-P_2O_5-K_2O/ha fertilizer application. Three sub-plots included: (a) N applied in all years (N all yr); (b) N applied in 2 of every 3 years (N 2/3 yr); and (c) no N applied any year (N 0 yr). In the year 2011, spring maize was planted on April 27 and harvested on September 24.

Ecological intensification treatment produced significantly higher grain yield (11.7 t/ha) than the FP treatment (11.1 kg/ha). Agronomic N efficiency (kg grain yield increase per kg N applied) was 42.3 kg/kg in the EI treatment and 29.2 kg/kg in the FP treatment. Similarly, partial factor productivity of N (kg grain yield per kg N applied) was 64.8 kg/kg with EI and 44.5 kg/kg with FP. EI with lower nutrient input obtained higher grain yield and nutrient use efficiency. Grain yield under N 2/3 yr treatment was significantly lower than under N all yr treatment, which demonstrated the value of N application in every spring maize growing season at the experimental site. *IPNI-20* ❖

Asia and Africa Group

South Asia

West India Region: Dr. Harmandeep Singh

Inventory of Available Soil Potassium Status and Modeling its Relationships with Potassium Content, Yield, and Quality of Sugarcane for Site-Specific Nutrient Management in Maharashtra

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Project Cooperators: S.H. Shinde, M.W. Pawar, P.V. Ghodake, and B.V. Undare

This project was initiated to delineate soil K fertility levels in the major sugarcane growing areas of Maharashtra and to develop a site-specific nutrient management (SSNM) package for maximum yield and quality of sugarcane Var. Co 9805. One hundred soil and plant samples were collected from farmers' field in Kolhapur, Sangli, and Satara districts of the state. Cane yield and juice quality data of the hundred fields were obtained after the sugarcane harvest. Initial soil K status and soil and plant K status at earthing up stage (120 days after planting) were correlated with cane yield and juice quality. Initial K status of the soil was found to be significantly correlated to brix percentage of juice.

Field experiments for developing nutrient management package of sugarcane variety Co-9805 were conducted in Manjari and Warna with four different levels (100%, 125%, 150%, and 175%) of recommended fertilizer rates (340 kg N, 170 kg P_2O_5 and 170 kg K_2O) as main treatments and six different levels (Control, S, S+Fe, S+Fe+Zn, S+Fe+Zn+B, S+Fe+Zn+B+Mn) of secondary and micronutrients as sub-plots. In Manjari, sugarcane variety Co-9805 responded significantly up to 150% of the recommended rate of fertilizer and cane yield was 107 t/ha. In Warna, highest cane yield (105 t/ha) was recorded at 175% of the current fertilizer recommendation. Interaction effects due to levels of NPK, secondary, and micronutrient application did not have any significant effect on cane yield at both the experimental locations. Maximum commercial cane sugar yield was recorded at 175% of the current fertilizer recommendation at Manjari (13.26 t/ha) and Warna (15.60 t/ha). Juice quality was, however, not affected by increased levels of NPK or application of secondary and micronutrients. The net return at Manjari increased significantly to INR 96,530/ha at 150% of the current recommended rate and the benefit: cost ratio was also highest (2.01) at this fertilization level. At Warna, net return (INR 93,243/ha) and benefit: cost ratio was highest at 175% of the current fertilizer recommendation, which was, however, not significantly different than 150% of the recommended fertilizer rate. Net return and benefit: cost ratio was not significantly influenced by secondary and micronutrient application. *India-002*

Development of a Soil Fertility Map as a Decision Support Tool for Fertilizer Recommendations for Citrus in India

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Citrus is one of the most important fruit crops in India. Average yield levels of citrus has remained stagnant over the past two decades. This project aims to break this yield stagnation through estimation of spatial nutrient variability in citrus orchards and use such information to develop site-specific nutrient management (SSNM) strategies. Two Khasi Mandarin orchards, one each at village Nong Khrah (20 year old) and Umsaitning (11 year old) of Ribhoi district in Meghalaya were studied. Geo-referenced rhizosphere soil samples (0 to 20 cm) were collected using three grid sizes (10 m x 10 m, 20 m x 20 m and 40 m x 40 m) at Nong Khrah and four grid sizes (10 m x 10 m, 20 m x 20 m, 40 m x 40 m and 60 m x 60 m) at Umsaitning. Fruit yield data were recorded from the orchards to delineate different production zones within the orchards. Soil samples were analyzed for pH, organic carbon, available macro and micronutrients and spatial variograms of these parameters were generated using a Geographical Information System (GIS).

Fruit yield variograms of different sampling scale showed that predicted yield levels within the orchard remained similar for 10 and 20 m grid sizes, but varied significantly at the 40 m grid size at Nong Khrah. In Umsaitning, fruit yields remained unchanged up to the 40 m grid, but changed abruptly at 60 m. This suggest that 20 m grid size is appropriate sampling scale in locations with greater topographical variations in terms of frequent piedmont (slope) and pediment (valley) variations, while the 40 m grid sampling density is sufficient where such variations are low. This was well highlighted in the fruit yield variograms where larger grid sizes often predicted erroneous fruit yield zones as compared to the ground truth data. Similar observations were found while interpreting variograms for pH, organic carbon as well as available macro and micronutrients. Variograms of soil test values at a 20 m grid sampling density were superimposed along with fruit yield variograms and distinct classes of soil properties were found for different yield zones within the orchards studied. This information will be used for developing SSNM recommendations for the different yield zones within the orchard. Similar studies will be done in Maharashtra and Madhya Pradesh. *India-003* ❖

Asia and Africa Group

South Asia

North & East India Regions and Bangladesh:

Dr. Kaushik Majumdar

Site-Specific Nutrient Management for Rice-Maize Cropping Systems in Bangladesh

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Site-specific nutrient management (SSNM) trials in rice-maize and rice-potato-maize systems were conducted in Comilla, Rajshahi, and Rangpur districts of Bangladesh. Omission of N reduced boro rice yield by 0.71, 2.13, and 1.34 t/ha in Comilla, Rajshahi, and Rangpur, respectively. However, the yield reduction due to omission of P and K was significant in Rangpur only. There were poor or no relationships between boro rice yield and total N, available P, and exchangeable K. The experimental data suggest that the estimated N rates would be between 90 to 110 kg/ha for the three districts. A maintenance dose of 6 to 10 kg/ha P and 40 kg/ha K may be recommended for boro rice in the rice-rice cropping system. Omission of N, P, and K significantly reduced the grain yield of rabi maize in all three locations. Yield decline due to K omission was higher than P omission in Comilla, but not in Rajshahi and Rangpur. Based on the lower yield observed in the N omission plots, N rates for rabi maize would be between 200 to 220 kg/ha in all three locations. The mean P dose for Comilla and Rangpur districts would be 16 kg/ha and that for Rajshahi would be 22 kg/ha. The mean K doses for Comilla, Rajshahi, and Rangpur would be 136, 65, and 36 kg/ha, respectively. Apparent K recovery in Comilla was highest among the three districts indicating that the soils are more deficient in K than in the other two districts.

In the rice-potato-maize system, omission of N decreased maize yield by 2.2, 2.6, and 1.0 t/ha in Comilla, Rangpur, and Rajshahi, respectively compared with the NPK treatment. Omission of P significantly decreased maize yield in all districts, but K omission significantly decreased yields in Comilla and Rajshahi only. The yield responses of kharif maize to N, P, and K were much smaller than in rabi maize. The low yield responses to N, P, and K in kharif maize were due to high amounts of fertilizer applied to the previous potato crop. Omission plot trial data from this experiment will be useful for developing site-specific fertilizer recommendations for the rice-maize system and for improving the Nutrient Manager and Nutrient Expert decision support tools that are currently under development and evaluation for Bangladesh. *Bangladesh-05*

Assessment of Soil Potassium Supplying Capacity from Soil Nutrient Reserves and Dissemination of Nutrient Management Technologies through Nutrient Manager

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Project Cooperators: Salim Uddin (BAU), M.A. Saleque (BRRI), and R. J. Buresh (IRRI).

The current project was initiated to estimate the magnitude and variation in soil K supplying capacity across a range of soils growing intensive rice-maize system in Bangladesh. Eighteen soil samples were collected from Dinajpur, Rangpur, Bagura, Rajshahi, Nawabganj, Sirajganj, Tangail, Faridpur, Jhinaidah, Sathkhira, and Comilla districts, representing diverse mineralogy and properties related to soil K supplying capacity. The samples were analyzed for pH, organic carbon, total N, available P, exchangeable K, S, Zn, Mg and Ca. The exchangeable K in the samples ranged from 0.149 to 0.317 cmol/kg.

A pot experiment with rice was conducted in the above soils with two treatments, Zero K (K0) and 100 mg K/kg soil (K100), in four replications. Other limiting nutrients were applied at a set dose so that the plants are not in deficient in any other nutrient except K. Rice seeds were sown and allowed to grow up to the booting stage, and then harvested. Plant height, numbers of tillers, and dry weight of plant and root were determined from each pot.

Dry matter yield in the K applied pots was significantly higher than the K omission pots in 7 out of the 18 studied soils. There was poor relationship between soil exchangeable K contents and dry matter yield

of rice. The dry matter yield range in the K0 and K100 pots were 10.1 to 33.3 g/pot and 14.8 to 39.2 g/pot, respectively. Analysis of the plant sample for K and other nutrient are in progress. After harvesting the first crop, soil in each pot was mixed and 15 days aged seedlings of rice were transplanted on December 4, 2011, in each pot as second crop. In a separate experiment, maize seeds were sown on November 10, 2011, which is now in V6 stage. Maize will be harvested at V8 stage and yield parameters as well as nutrient uptake will be analyzed. Both rice and maize will be grown for 6 to 8 crop cycles in the same pot to estimate K supplying capacity of the soils. The results from the pot experiment will be validated in two field experiments with five different rates of K in the upcoming rabi maize and boro rice. *Bangladesh-006*

Importance of Soil Test-Based Nutrient Application through Farmers' Participatory Approach in Red and Lateritic Soils of West Bengal

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The current study was initiated in 2011 to assess the use of Geographic Information System (GIS)-based soil fertility maps for field specific fertilizer decision-making in smallholder systems. On-farm studies done in this project have established that GIS map-based fertilizer recommendation in rice-potato-sesame cropping system produced equivalent yield and economic benefit as actual soil test. Economic analysis also showed that a 100 m grid-based sampling as opposed to plot by plot sampling can reduce the cost of soil analysis substantially (one-seventh), while still producing comparable net returns.

Another set of experiments were set up to check whether a higher grid size of sampling could be adopted to further decrease soil sampling cost. Three different fertility maps of the study area were prepared using 50 m, 100 m, and 250 m grid of soil sampling. Fertilizer recommendation from these grid-size maps were evaluated against the actual soil-test based fertilizer recommendation in the rice-potato-sesame cropping system. Generalized recommendation practiced in the study area was included in the experiment as a control. Results from rice suggested that plant height (cm), leaf area index, dry matter accumulation (g/m^2), crop growth rate (g/m^2/day), number of panicles/m^2, grains/panicle, yield, and economic return were similar in 50 and 100 m map-based recommendation and actual soil samples. However, the parameters evaluated were significantly lower in 250 m map-based fertilizer recommendation. Similar results were obtained in potato and sesame. An assessment of system net return in rice-potato-sesame under the four evaluated fertilization strategies showed that average net return in the 50 and 100 m map-based recommendation and actual soil test were significantly higher (INR 14,567/ha) than the 250 m grid-based fertilizer recommendation. Average system net return in the 50 and 100 m map-based recommendation and actual soil test were higher by INR 28,830/ha as compared to the generalized fertilizer recommendation.

The results from the study suggest that 250 m grid-based fertility maps were unable to capture fertility variations at the village scale (area < 100 ha) and sampling density of one sample/ha is the suitable option. However, such sampling density may not be practical at higher scale (district or state) and the sampling density at such scales should be based on an overall balance between application cost and return from field specific nutrient management practices. *EZ-India-43*

GIS-based Spatial Variability Mapping of Agricultural Holdings for Precision Nutrient Management in the Red and Lateritic Soil Zone

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Project Cooperator: T. Ravishankar, National Remote Sensing Centre, Department of Space, Govt. of India

This project aims to assess the correlations between soil parameters, yield, and actual crop response to applied nutrients in an intensively cultivated village in the red and lateritic soil zone of West Bengal to develop a Geographic Information System (GIS)-based model for nutrient decision support in rice-wheat cropping system. Based on the nutrient variability map of the study area, five on-farm trials were set up in wheat with seven treatments including: Control, Farmer practice, State recommendation (100% NPK), 100% NPK+S+B+Zn, 100% PK+S+B+Zn, 100% NK+S+B+Zn, 100% NP+S+B+Zn. Wheat yield was generally poor in the season due to shorter winter and low winter temperature. Mean wheat yield was highest (2.5 t/ha) in the 100% NPK+S+B+Zn treatment and average reduction in yield due to omission of N, P, and K were 0.95, 0.81, and 0.7 t/ha, respectively.

In the following rice season, yield and nutrient variability data assessed from the village were used in a GIS platform to identify 8 management zones within the village. The management zone map was merged

with the actual village map accessed from Google Earth and 8 on-farm trials, one in each management zone, were set up in monsoon rice. The following treatments were used to assess the suitability of the fertilization strategy based on management zone approach as well as to estimate nutrient response variability between the management zones: T1: Farmers' practice; T2: Soil-test based targeted yield approach; T3: Management zone approach using GIS map; T4: Ample NPK; T5: Ample PK; T6: Ample NK; and T7: Ample NP. Rice yield was highest (4.2 t/ha) under targeted yield approach treatment in all the management zones with a range of 4.0 to 4.4 t/ha. The management zone-based approach and ample NPK treatments resulted in equivalent average yield levels of 3.9 and 4.0 t/ha respectively. Average yield loss in N, P, and K omission plots were 2.1 (range 1.9 to 2.3), 1.8 (range 1.6 to 1.9) and 1.6 (range 1.3 to 1.7) t/ha, respectively. Similar experiments in wheat, with an additional treatment of Nutrient Expert decision support tool based nutrient recommendation, is in progress. *India-001*

Addressing Multi-Nutrient Deficiencies through Site-Specific Nutrient Management

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Project Cooperators: Dhyan Singh (Principal Scientist) Anand Swarup (Division of Soil Science and Agricultural Chemistry), K.S. Yadav, and Krishi Vigyan Kendra (IARI), Shikohpur

Incidence and expansion of multi-nutrient deficiencies in Indian soils owing to inadequate and unbalanced nutrient input is considered as one of the major reasons for decline in factor productivity of crops. The problem is more acute in intensively cropped areas, where annual nutrient removal by the crops often far exceeds replenishments. Diagnostic surveys indicate that in several high productivity areas of irrigated ecosystems, farmers often resort to excessive use of fertilizer N to maintain the yields at levels attained previously with relatively lower fertilizer rates. Such indiscriminate use of N fertilizers not only aggravates soil fertility depletion with respect to nutrients other than N, but also proves ultimately harmful in terms of low nutrient use efficiency, poor quality of produce, enhanced susceptibility of crops to biotic and abiotic stresses, and a potential threat of groundwater.

In the present era of multi-nutrient deficiencies, site-specific nutrient management (SSNM) is one of the good options to arrest the decline in soil fertility. A thorough understanding of the nature and extent of nutrient deficiencies in the soils of different agro-ecologies is a pre-requisite for developing SSNM strategies. In order to bridge the existing knowledge gaps on these aspects, the present research project was initiated for assessment of multi-nutrient deficiencies in a village or a cluster of villages in the agriculturally important agro-ecological subregions (AESRs). Widespread multi-nutrient deficiencies involving 2 to 5 nutrients were observed in different AESRs. SSNM strategies based on such information produced better yield and economics than state recommendation and farmers' fertilizer practice in several cropping systems. Attempts were also made to establish relationships between spread of nutrient deficiencies and nutrient use by the farmers in the sampled villages of different AESRs. Results indicated significant relationship between P and K deficiencies with the use of these nutrients in some AESRs, while the relationships were generally inconsistent for other nutrients. Multi-nutrient deficiency maps of the sampled areas from different AESRs are being developed utilizing soil test data and GPS coordinates of sampling points. Information on assessment of multi-nutrient deficiencies in different AESRs and from SSNM experiments are being compiled into a research bulletin. *India-004*

Fertility Mapping and Balanced Fertilization for Sustaining Higher Productivity of Pearl Millet-Wheat Cropping System in Agra District

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The project assessed a plant-based approach to develop SSNM strategies for pearl millet-wheat system. Omission plot trials in farmers' fields helped assess the wheat nutrient response in the study area. This information was used in the Nutrient Expert (NE) for wheat, a nutrient application decision support tool to develop field specific nutrient recommendation. The relative performance of NE generated fertilizer recommendation was compared to a soil-test based recommendation (OPT) and the existing general fertilization practice (SR) in 16 farmers' field trials. The trials assessed five treatments: (i) OPT (180 kg N, 90 kg P_2O_5, 100 kg K_2O and 40 kg S/ha); (ii) OPT-N; (iii) OPT-P; (iv) OPT-K; (v) State Recommendation (120 kg N, 60 kg P_2O_5, 40 kg K_2O/ha); and (vi) NE (140 kg N, 68 kg P_2O_5 and 81 kg K_2O/ha) for a target yield of 6 t/ha. The soil test-based recommendation produced the highest wheat grain yield (5,847 kg/ha) followed by nutrient recommendation from NE (5,639 kg/ha). Average grain yield in farmers' fields under State Recommendation (SR) was 5,223 kg/ha. Omission of nutrients reduced wheat grain yield by 38.1 % (- N), 20.7 % (-P), and 23.1 % (-K). The optimum treatment (OPT) produced higher net returns (INR 57,673/ha) than SR (INR 50,917/

ha), but was at par with NE (INR 56,144/ha). Benefit: Cost ratio of the NE, OPT, and SR treatments were 2.25, 2.22, and 2.11, respectively.

Pearl millet was grown in the following kharif season in farmers' field with the following treatments: (i) OPT (120-70-100-30 kg N-P-K-S/ha); (ii) OPT- N; (iii) OPT- P; (iv) OPT - K; and (v) OPT - S to develop SSNM strategies. The nutrient rate in the optimum treatment was based on omission plot studies done in the previous year. Grain yield (4,147 kg/ha), stover yield (8,204 kg/ha) and net income (INR 25,659/ha) were highest in the optimum treatment. Average response for N, P and K were ≈1.5, 1.0 and 0.5 t/ha, respectively. Average yield reductions in pearl millet across 16 farmers' fields due to N, P, K, and S omissions were 34.1, 22.1, 11.2, and 4.6 %, respectively. *India-006*

Site-Specific Nutrient Management for Rice-Wheat in the Punjab

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Project Cooperator: Naveen Gupta

This study was initiated to develop and implement a site-specific nutrient management (SSNM) strategy for the rice-wheat system under conventional and no-till cultivation. Three types of trials were conducted 1) omission plot trials with four treatments (-N, -P, -K, and NPK); 2) omission plot trials in direct seeded rice (DSR) and puddled transplanted rice (PTR) with nine treatments (-N, -P, -K, NPK, Full NP reduced K, Full NK reduced P, Full N reduced PK, Reduced N full PK and -Zn); and 3) Nutrient Expert (NE), a field-specific nutrient recommendation tool for wheat, evaluation trials with three treatments (farmer fertilizer practice, state recommended fertilization, and NE-based fertilizer recommendation).

DSR yielded higher than PTR in the ample NPK plot. However, yield loss in N, P and K omission plots in DSR (2,278, 1,481 and 1,164 kg/ha, respectively) was greater in DSR than in PTR (1,749, 918 and 696 kg/ha, respectively). This might be due to higher availability of soil nutrients under puddled conditions. Reduction of N, P and K rates by 20, 25, and 50% respectively led to average yield decline of more than 1 t/ha in DSR and about 0.7 t/ha in PTR for each nutrient. This indicated that reduction in nutrient rates, even for P and K, could cause significant economic loss. Interestingly, omission of Zn caused an average yield decline of 833 kg/ha in DSR and 522 kg/ha in PTR, thus, highlighting the issue of extensive Zn deficiency in Punjab soils.

Average wheat yields under zero and conventional tillage methods were 4,965 and 4,770 kg/ha, respectively, in ample NPK treatment plots. Nitrogen was the most limiting nutrient across sites, followed by P and K. Yield decline due to nutrient omission was higher in zero till than in conventional tilled wheat. Across all sites, the NE-based fertilizer recommendation recorded the highest yield of 6,200 kg/ha in zero till wheat and 5,633 kg/ha in conventionally tilled wheat. Average yield increase through NE recommendation in wheat grown after rice was 700 kg/ha over State recommendation and 900 kg/ha over farmers' practice. Similar yield increases (450 and 1,013 kg/ha over state recommendation and farmers' practice, respectively) were also noticed in cotton-wheat system. Application of N in equal splits as basal and at crown root initiation stage with wheat performed best in Punjab. *India-007*

Site-Specific Nutrient Management for Rice-Wheat in Haryana

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The project was initiated to develop site-specific nutrient management (SSNM) strategy for rice-wheat cropping systems grown under varying tillage and residue management scenarios. Omission plot trials with four treatments (-N, -P, -K, ample NPK) were conducted in wheat and rice to assess soil nutrient supplying capacity in zero- and conventional-tilled wheat with different levels of residue loads, and in direct seeded rice (DSR) and puddled transplanted rice (PTR). Evaluation trials of Nutrient Expert (NE) for Wheat, a nutrient decision support tool developed by IPNI, were also conducted with three treatments (Farmer fertilizer practice, State recommended fertilization, and NE-based fertilizer recommendation) to assess yield and economic advantages of using the tool.

Omission plot experiments showed that N is the most limiting nutrient across sites. Results from zero-till wheat trials showed that ample NPK plot yield was higher when full residue of the previous rice crop was retained in the field. The yield loss due to omission of N, as compared to the ample NPK plot, was comparable in full- and partial-residue retained plots (average 3.1 t/ha) but was less in no residue plots (average 2.7 t/ha). This might be due to more N immobilization in plots where crop residues were retained. Yield loss due to K omission was lowest (0.4 t/ha) where full rice residue was retained, which is probably due to release and availability of K from rice residues. Average yield loss due to P omission was about 0.8 t/ha across

all residue retention scenarios. The yield in ample NPK plots in DSR and PTR was not significantly different. The yield losses due to omission of N, P and K, as compared to the ample NPK plot, were 1.4, 0.5 and 0.3 t/ha and were also not significantly different for DSR and PTR. The yield in ample NPK and omission plot were highly variable across sites highlighting the difference in soil nutrient supplying capacity. The first year evaluation trials of NE-based fertilizer recommendations showed an improvement in yield by 650 and 562 kg/ha respectively in zero-till and conventional till plots over farmers' fertilizer practice. Results revealed that most of the yield gain was associated primarily with increased potash recommendation by NE. *India-008*

Site-Specific Nutrient Management for Rice-Maize Systems in Bihar

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Project Cooperator: Vishal Bahadur Shahi

This project was initiated to assess the effect of contrasting tillage practices on nutrient supplying capacity of soils in the lower-gangetic Plains region of India, and utilize the information generated for site-specific nutrient management (SSNM) in rice and maize crops. Nutrient omission trials in rabi (winter) maize and kharif (summer) rice were set up in farm fields in contrasting tillage practices and growing environments. The trials consisted of four treatments: a) ample NPK, b) N Omission (ample PK), c) P Omission (ample NK), and d) K Omission (ample NP). Ample NPK treatment rates were chosen to avoid any nutrient limitation. All plots received uniform rates of deficient secondary and micronutrients. For rice, reduced rates of P and K (25 and 50% of the ample rate, respectively) were also included as treatments to ascertain whether such rates are economically more viable. Nutrient Expert, a nutrient decision support tool for hybrid maize developed by IPNI, was also validated in kharif maize against the existing nutrient management practices.

Maize yields in ample NPK plot under zero and conventional till conditions were 8,169 and 7,328 kg/ha, respectively. For winter maize the average nutrient response to N, P, and K, as determined from the yield difference between ample NPK plot and N, P, or K omission plots, were 3,074, 1,213, and 941 kg/ha, respectively, for zero-tillage conditions. The N, P, and K responses for conventionally tilled fields were 2,744, 1,105, and 752 kg/ha, respectively. The experimental data also suggested that nutrient omission would cause higher yield loss in zero till than in conventional till plots. Similarly, nutrient omission studies in kharif rice showed that N, P, and K omissions reduced rice yields by 44, 18, and 11%, respectively, when compared with the ample NPK treatment yield. Decreasing P and K rates by 25 and 50%, respectively, from the ample PK rates, reduced rice yields by 8-9% compared to ample NPK treatment plot yields.

Averaged across ten sites, nutrient recommendations from NE increased average maize yields by 2,513 and 600 kg/ha over existing farmers practice and state recommendation, respectively. The NE tool, which was modified based on the first year experimental data, is now being validated further at more sites. *India-009*

Comparative Evaluation of Nutrient Dynamics under Conventional and No-till Systems of Crop Establishment in Rice-Wheat and Rice-Maize Cropping Systems

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Project Cooperators: M.C. Meena, Anand Swarup, M.L. Jat, R.K. Gupta, and Animesh Singh

Field experiments on rice-wheat, rice-rice, and maize-wheat cropping systems were conducted in cultivators' fields at Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand, and West Bengal to study the effect of crop establishment methods on the changes in soil fertility, develop site-specific nutrient management (SSNM) for the above cropping systems under different tillage and residue management scenarios and assess the impact of different crop establishment method on the annual productivity and economic returns. Emphasis was on establishing the on-farm experiments within a relatively small geographical area with a wide variation in soil texture, landscape, and other critical factors affecting the indigenous supply of N, P, and K. Initial and post-harvest soil samples were collected following standard sampling protocols to analyze pH, EC, organic C, texture and available N, P, and K. Samples of irrigation water were also collected for total Ca, Mg, and K content. Crop yields and yield attributes were recorded at the time of maturity. At harvest, grain and straw samples were collected for analysis of nutrient contents and uptake of nutrient by wheat across sites..

Post-harvest plant analysis from more than 1,200 wheat experimental sites across six major wheat growing states showed that average N, P, and K contents in the grain were 19.2, 3.2, and 3.8 g/kg, respectively. Average straw nutrient content across all sites were 4.3, 0.64, and 15.5 g/kg of N, P and K respectively while average protein content in grain was 12 %. Nutrient uptake by wheat was determined in plant samples for estimating N, P, and K requirement. Average N uptake in the experimental sites was 106 kg/ha, while P and K uptake were 17.1 and 104.5 kg/ha, respectively. Nutrient harvest index, which highlights the partitioning

of mineral nutrients in wheat grain and straw, were 0.78, 0.78, and 0.16 respectively for N, P, and K. This suggests that there is a high potential of K export from field with harvested straw. Such high removal/mining of K with straw needs to be compensated with external application, unless a large portion of the straw is returned back to the field. Analysis of soil and plant samples from rice and maize experiments are in progress. These data will be used to develop SSNM strategies for the three major cropping systems under study.
India-017

Global Maize Project in India: Ranchi, Jharkhand

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Project Cooperators: A.K. Sarkar and S. Karmakar

Optimal nutrient management strategies for maize-wheat system were initiated in the Western Plateau Region of Jharkhand. Three experiments were conducted during 2011 with wheat (variety DBW 17) in rabi (December 2010 to April 2011) and maize (Pioneer 30V92) during kharif (June to October, 2011).

Highest grain yield of maize (7.0 t/ha) and wheat (4.1 t/ha) were obtained with application of N: P_2O_5:K_2O at 180: 90: 100 kg/ha for maize and 130: 70: 60 kg/ha for wheat under the ecological intensification (EI) treatment in the long-term system evaluation of EI and farmers' fertilization practices (FFP), Maize and wheat grain yields were 2.27 and 2.2 t/ha, respectively, under the FFP treatment. The EI treatment recorded 104.6 % higher maize equivalent yield over FFP.

Studies on the effect of rate and time of N application on maize-wheat system yield showed that application of N in maize at 240 kg/ha produced maximum grain yield (7.5 t/ha) that was at par with yield obtained (7.1 t/ha) with N application at 160 kg/ha in 3 splits on the basis of a leaf color chart (LCC). Nitrogen applied at 150 kg/ha in 2 splits in wheat resulted in highest grain yield (5.1 t/ha). Percent increase in yield of the maize-wheat system, over no application of N, was highest (254%) with the application of 240 and 150 kg N/ha in maize and wheat, respectively.

In the omission plot experiment, wheat yield was highest (4.8 t/ha) in the ample NPK (150:110:100) plot. Omission of N and P from the ample NPK treatment reduced yield by about 4 and 2.1 t/ha, respectively, with no reduction in yield due to K omission. In the following maize season, both ample NPK and omission plots were divided into two equal plots and residues of the previous wheat crop were retained in one plot and were completely removed from the other plot. Maize yield in the ample NPK (250:120:120) plots, with and without residues, were 8.36 and 8.28 t/ha, respectively. The lowest yield of maize (0.8 t/ha) was obtained in the N omission plot where wheat residues were retained while the yield was slightly higher (1.1 t/ha) in the N omission plot with no residues retained. Reduction in maize equivalent yield of the system due to nutrient omission, as compared to ample NPK plot, followed the order N (84.8%) > K (42.4%) > P (32.1%).

IPNI-22 ❖

Asia and Africa Group

South Asia

South India Region and Sri Lanka: Dr. T. Satyanarayana

Fertility Mapping through Spatial Variability in Rice Growing Soils of Cuddalore District, Tamil Nadu

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Project Cooperator: K.P. Ragunath

In this study, spatial variability maps were created on the GIS platform using soil fertility data of the known sampled points and GPS readings of individual locations. These maps were then used to determine the fertility status of unsampled farmer's plots. Based on the predicted fertility, four management zones were formed, viz., Zone I (Low N: Low P: High K), Zone II (Low N: Low P: Medium K), Zone III (Low N: Medium P: High K), and Zone IV (Low N: Medium P: Medium K). On-farm experiments were conducted during kharif 2011 taking rice as a test crop at 12 locations with three experiments in each management zone. Fertilizer recommendations for yield targets of 5 and 6 t/ha generated in each management zone using variability maps and DSSIFER (a computerized fertilizer recommendation system) were compared with state government recommendations (150:50:50 kg/ha $N:P_2O_5:K_2O$) and farmer practice (160:140:60 kg/ha $N:P_2O_5:K_2O$) across all the locations.

Nutrient application for a yield target of 6 t/ha resulted in an average rice yield of 6.2 t/ha (range 6 to 6.3 t/ha) across the management zones. Similar trend was observed for targeted yield of 5 t/ha with an average yield of 5.2 t/ha. Thus, target yields were attained at all the experimental locations across the management zones. Moreover, there was a statistically significant increase in grain yield with 6 t/ha yield target vis-a-vis state recommendation (5.1 t/ha, 21%) and farmer practice (3.9 t/ha, 57%). In contrast, however, a significant yield difference between targeted yield of 5 t/ha and state recommendation was noticed only at three of the four management zones. Recommendations based on fertility maps resulted in a net return of INR 34,990/ha with a benefit:cost ratio of 2.29 at a yield level of 6 t/ha. This return was INR 9,282/ha higher over the state recommendation and INR 26,246/ha higher over farmer practice. These encouraging results notwithstanding, there is a need to scale up the approach for larger areas. This project was completed in 2011. *India-012*

Site-Specific Nutrient Management for Chilli in Kalliyoor Panchayat of Kerala

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The study was initiated after recognizing the decline in productivity of chillies in the experimental region and the need to generate quantitative knowledge on efficient nutrient management strategy in chillies using the principles of site-specific nutrient management (SSNM). Four representative chilli growing sites were selected based on the variation in soil fertility. Nutrient omission plot studies were conducted to determine the yield obtained from indigenous nutrient supply. Results from nutrient omission trials, initial survey information and soil analysis data were considered to set yield targets of 12 and 16 t/ha. Field-specific nutrient recommendations were developed using the relationship between yield and nutrient uptake at multiple harvests, considering the indigenous nutrient supply, yield targets, and nutrient demand as a function of the interactions between nutrients. On-farm trials were conducted to assess the recommendations generated in this study which were compared with state recommendation and farmer practice.

Omission plot studies averaged over four locations indicated that NPK application (275-140-125) resulted in 13.2 t/ha of chilli yield, which was 55% higher than obtained under farmer practice (80-55-25). Yields obtained in plots omitting N, P, and K were 10.6, 13.0, and 10.9 t/ha, respectively, probably because of high soil test P values. Averaged over three pickings, nutrient application for a yield target of 12 and 16 t/ha resulted in a chilli yield of 11.8 and 17.3 t/ha. Higher yield in SSNM plots was possibly because of thrice the number of fruits per plant in these plots than in farmer practice. Similarly, better quality fruits with

high capsaicin content of 1.5% were also observed at 16 t/ha yield level. Significantly higher net returns and B:C ratios were realized at 16 t/ha yield level (INR 275,645 and 4.89) compared to 12 t/ha yield level (INR 166,570 and 3.43). The returns in state recommendation and farmer practice were only INR 103,000 and INR 42,500 with B:C ratios of 2.63 and 1.69, respectively. Thus, the study indicated that SSNM-based recommendations increased the productivity of green chillies by 2.25 and 3.3 times in Kalliyoor Panchayat of Kerala with a yield target of 12 and 16 t/ha, respectively. *India-013*

Improving Nutrient Use Efficiency and Profitability in Rainfed Production Systems

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Improving nutrient use efficiency in rainfed areas has always been a major challenge, which could be addressed through balanced nutrition and soil moisture conservation. This project was established to study the impact of balanced nutrient use coupled with conservation tillage systems on productivity, profitability and nutrient use efficiency in maize-horsegram cropping sequence.

Highest grain (4.7 t/ha) and stover (7.9 t/ha) yields of maize were obtained with balanced nutrient treatment receiving 150-60-80 kg N-P_2O_5-K_2O/ha along with 30 kg S, 10 kg Zn, and 0.5 kg B for a yield target of 4 t/ha. However, no significant difference in grain and stover yield of maize was observed among the tillage systems during the first year of maize crop. In case of horsegram, grown on residual fertility applied to maize, yields differed significantly among the tillage options. Horsegram yields varied from 264 to 443 kg/ha in conventional tillage system with highest yield recorded in S omission plot (443 kg/ha) followed by optimum treatment (418 kg/ha). In conservation tillage system, optimum treatment recorded low yield (578 kg/ha) compared to omission of S (643 kg/ha), P (635 kg/ha), N (618 kg/ha), and Zn (596 kg/ha), with the lowest yield recorded in absolute control (464 kg/ha). There is a need to understand nutrient dynamics in conservation tillage system for explaining such yield variations. Further, soil properties did not change with tillage options. Initial soil reaction (pH) of 5.1 increased to 5.6 after the harvest of horsegram in both the tillage systems, whereas the initial soil organic carbon of 0.34% increased slightly to 0.43% in the conventional till and to 0.41% in conservation tillage plots. Optimum nutrient treatment had the highest residue cover (45%) followed by omission of Zn (42%), K & S (41%) and B (40%) with the least residue cover noticed in absolute control (31%). This emphasizes the importance of balanced nutrition for maximum residue retention in rainfed areas. Calculations for nutrient use efficiency and economics of balanced nutrition in rainfed areas are currently being done. This project was started in mid-2010 and is planned to continue for 3 years until mid-2013. *India-014*

Maximizing Yield of Groundnut Through Improved Nutrient Management Practices in Acid Soils of Orissa

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Groundnut is an important oil seed crop of Orissa, cultivated throughout the year on about 256,000 ha area with a production of 458,000 t. Currently, its productivity is declining due to sub-optimal nutrient application. Also, the estimated gap between current (1,791 kg/ha) and attainable (>3,000 kg/ha) yields is quite wide. We hypothesized that an improved nutrient management strategy will improve yield and quality of groundnut.

For the study, a survey of important groundnut growing areas of Orissa was conducted to identify soil related constraints and to collect information on cropping history, current nutrient additions, and crop yields in the region. Ten locations representing coarse-textured sandy soils with acidic soil reaction, and areas responding to secondary and micronutrient application, were identified. Soil samples were collected and analyzed for soil properties including available nutrients. The soils were acidic in reaction, low in organic C, low in available N and K, medium in available P, and deficient in available Zn, S, and B. Five field experiments were laid out during both kharif (summer, rainy) and rabi (winter) seasons of 2011 at the identified locations. The treatments compared site-specific nutrient management (SSNM) recommendation (N+P+K+Ca+S+Zn+B with doses varying from site-to-site based on soil test results), state recommendation (20-40-40 kg N-P_2O_5-K_2O/ha with 45 kg S, 2.5 kg Zn, 1.0 kg B and 500 kg Ca), farmer practice (23-76-56 kg N-P_2O_5-K_2O/ha with 11 kg S), and seven nutrient omission plots (i.e., - N, - P, - K, - Ca, - S, - Zn, and - B).

Results at one of the on-station locations indicated that SSNM (30-50-60 kg N-P_2O_5-K_2O/ha along with 56 kg S, 3.3 kg Zn, 1.2 kg B and 500 kg Ca) resulted in 1,140 kg/ha of groundnut yield, which was about 7% higher than the state average yield (1,070 kg/ha). Low yield in kharif season is attributed to late sowing and unfavorable weather conditions at the time of sowing. Yields loss due to omission of P, Ca, and S were 850, 920, and 950 kg/ha, respectively. The data for other locations is being compiled. This project was started in 2011 and is planned to continue until mid-2012. *India-015*

Site-Specific Nutrient Management in Maize Growing Districts of Tamil Nadu

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Maize is becoming an important crop in Tamil Nadu, currently being cultivated in 244,200 ha area with a production of 1.1 M t. However, the current productivity levels of maize average only about 4.7 t/ha when compared to it's yield potential of more than 10 t/ha. Inadequate and improper fertilization, sub-optimal official state recommendations, and lack of focus on the use of secondary- and micro-nutrients are some of the key factors responsible for low maize yields. Moreover, application of fertilizers varies from field-to-field, and looking at the extent of variation in soil fertility across the farmer fields, single homogenous state recommendation may not be very helpful in improving maize yields. Conservation tillage systems pose greater challenges for farmers due to lack of information on efficient nutrient management strategies under these systems. The current project goal was to develop site-specific fertilizer recommendations using Nutrient Expert decision support tool in four major maize growing districts of Tamil Nadu. For this, 16 locations representing variable maize growing environments were selected in Perambalur, Thanjavur, Vagarai, and Coimbatore districts of Tamil Nadu, and a set of two experiments under conventional and conservational tillage systems were conducted at four locations in each district. The first experiment compared Nutrient Expert-based fertilizer recommendation with state recommendation and farmer practice, while the second experiment looked at the yield response with ample NPK (250-100-120 kg N-P_2O_5-K_2O/ha) along with nutrient omission treatments for N, P, and K, respectively. The experimental soils were alkaline in reaction (pH 8.1 to 8.3), low to medium in organic C (0.41 to 0.90%), low to medium in available N (176 to 252 kg/ha), and medium to high in both available P (11 to 35 kg/ha) and available K (270 to 640 kg/ha).

Results obtained so far from two locations indicated no significant difference in grain and stover yields of maize among the different crop establishment systems. Highest grain yield (8.6 t/ha) was obtained with Nutrient Expert-based recommendation followed by state recommendation (8.1 t/ha) and farmer practice (6.9 t/ha). Yields due to ample NPK and omission of N, P, and K were 7.48, 7.08, 7.16, and 7.13 t/ha, respectively. The project is expected to continue until mid-2013. *India-018*

Site-Specific Nutrient Management (SSNM) for Maximum Economic Yield and Quality of Transgenic Cotton in Northern Karnataka

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Northern Karnataka has currently 70% of the total cotton area under transgenic (Bt) cotton in India. However, low average productivity and limited information on nutrient management in Bt cotton led to this study evaluating the effect of site-specific nutrient management (SSNM) on transgenic cotton.

On-station experiments conducted at Dharwad and Sirugappa for 3 years revealed that planting geometry of 90 x 60 cm at Dharwad and 90 x 30 cm at Sirugappa resulted in higher seed cotton yield of 2,945 and 2,335 kg/ha, respectively. Similarly, nutrient application for a yield target of 4,000 kg/ha resulted in a seed cotton yield of 3.5 and 2.4 t/ha at Dharwad and Siruguppa, respectively. Higher net returns of INR 75,029/ha and benefit-to-cost (B:C) ratio of 4.06 were observed at Dharwad as opposed to only INR 45,077/ha and B:C ratio of 3.03 at Siruguppa. This indicated that target yields were attained only under Dharwad conditions.

Results from Dharwad were tested and confirmed in the farmer fields at 15 locations representing soil types varying from medium-to-deep black and red soils. SSNM recommendations for yield targets of 3,000 kg/ha (160:75:100 N:P_2O_5:K_2O kg/ha + 25 kg $ZnSO_4$) and 4,000 kg/ha (220:100:160 N:P_2O_5:K_2O kg/ha + 25 kg $ZnSO_4$) were compared with state recommendation (100:50:50 N:P_2O_5:K_2O kg/ha) and farmer practice (average of 124:72:56 N:P_2O_5:K_2O kg/ha). Nutrient application for a yield target of 3,000 kg/ha resulted in average cotton yields of 2,900 (range 2,500 to 3,180) kg/ha. Nutrient application for 4,000 kg/ha resulted in an average seed cotton yield of 3,340 kg/ha across the farmer fields with yield targets not attained at majority of locations. Using state fertilizer recommendations, cotton yields varied from 2,000 to 2,750 kg/ha, and with farmer practice, they varied between 1,900 and 2,950 kg/ha, respectively. Thus, SSNM recommendations for 3,000 kg/ha resulted in a yield increase of 19% over farmer practice (2,440 kg/ha) and 20% over state recommendation (2,420 kg/ha). The results were shown to farmers through organized field days and have also been incorporated in the cotton video currently in production. The results will also be presented in the state review meeting during October 2012 for revising state fertilizer recommendation for Bt cotton. *India-010*

Site-Specific Nutrient Management for Optimizing Productivity of Rice-Maize Cropping in the Krishna and Godavari Agro-Climatic Zones of Andhra Pradesh

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Project Cooperators: R. Veeraraghavaiah, Agricultural College, Bapatla and G. Subbaiah, Agricultural College, Bapatla

Rice-maize cropping system in Andhra Pradesh comprises about 50% of the total area under this system (525,000 ha) in India. However, there is a lack of adequate knowledge on efficient nutrient management practices, resulting in uncertain yields and raising doubts on the long-term sustainability of this cropping system. This project was initiated to develop guidelines for nutrient use in the three major rice-maize growing districts of Andhra Pradesh using the principles of site-specific nutrient management (SSNM). Fifteen locations representing variable management zones of the region were selected for the study, and yield targets of 6 and 12 t/ha were set for rice and maize, respectively. Ample NPK rates at 180-70-80 for rice and 255-170-240 for maize were proposed at all locations to achieve the yield target. These rates were also compared with the state fertilizer recommendations of 120-40-40 kg N-P_2O_5-K_2O/ha, respectively, for rice and 120-60-60 kg N-P_2O_5-K_2O/ha, respectively, for maize as well as with farmer practices.

Nutrient application in maize for a yield target of 12 t/ha resulted in an average maize yield of 10.2 t/ha (range 8.1 to 11.9 t/ha across different sites). Target yields were attained at six of the 15 experimental sites. Inadequate plant population coupled with delayed basal fertilizer applications by 20 to 25 days could have contributed to yield reductions at nine sites. Maize yields with state recommendation ranged from 7.5 to 10.3 t/ha with an average of 8.6 t/ha. Similarly, maize yields with farmer practice varied between 6.7 and 8.7 t/ha, with an average of 7.9 t/ha. Thus, SSNM-based fertilizer recommendations resulted in a yield increase of 19% over state recommendation and 28% over farmer practice. Omitting N, P, and K from the ample NPK rates resulted in yields of 5.5, 6.9, and 7.8 t/ha of maize, respectively. Reducing P and K rates either individually or jointly from ample NPK did result in a significant yield difference across the locations, thereby indicating yield response to both these nutrients. The results from this study were used to develop Nutrient Expert Decision Support tool for Andhra Pradesh, and the tool is currently being used for providing field-specific fertilizer recommendations. The project was completed in 2011. *India-011*

Global Maize Project in India: Maize-Wheat Cropping System in Northern Karnataka

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Project Cooperator: Y.R. Aladakatti, Associate Professor (Agronomy), Dharward

Evaluation of the maize-wheat cropping systems using ecological intensification (EI) with application of 180-90-100 kg N-P_2O_5-K_2O/ha and FP (farmer practice) with application of 115-52-45 kg/ha resulted in maize grain yields of 3.9 t/ha and 2.8 t/ha, respectively. A 23% higher net return of INR 24,003/ha with benefit-to-cost (B:C) ratio of 2.67 was realized with EI than with FP. Grain yield of wheat using EI with application of 130-70-60 kg N-P_2O_5-K_2O and FP with application of 115-52-45 kg/ha was 4.1 t/ha and 3.2 t/ha, respectively.

Rate and application studies found that 240 kg N/ha application could generate 7.2 t/ha maize, which was higher than the 6.2 t/ha produced with 160 kg N/ha. Net returns and B:C ratios with 240 and 160 kg N/ha were INR 48,067 (3.76) and INR 41,206 (3.59), respectively. Application of N in three splits with and without the use of leaf color charts (LCC) resulted in equivalent maize yields of 4.9 and 4.7 t/ha, but these results were superior to N provided in two splits. Grain yields in the succeeding wheat crop were 4.2 and 3.6 t/ha using 150 and 100 kg N/ha, respectively. Application of N in three splits with and without the use of leaf color charts (LCC) resulted in equivalent wheat yields of 3.1 t/ha. However, the results were superior to N provided in two splits, which recorded a grain yield of 2.7 t/ha, respectively.

Studies on indigenous soil nutrient supply indicated ample NPK (250-120-120) and NPK rates derived through site-specific nutrient management (SSNM) (200-90-100) resulted in maize yields of 7.7 and 6.9 t/ha, respectively. Omitting N, P, and K from ample NPK resulted in a maize yield of 2.7, 6.1, and 6.6 t/ha, respectively. In wheat, ample NPK (150-110-100) and SSNM rates (120-60-50) produced 4.2 and 4.1 t/ha. Nitrogen, P, and K omission recorded a wheat yield of 1.8, 3.8, and 3.9 t/ha, respectively.

Considering the results obtained from experiments in the previous year, N rate for wheat in the EI treatment was slightly improved from 130 to 150 kg/ha. Soil and plant analysis have been carried out and the data on nutrient uptake is currently being compiled at the time of this report. *IPNI-23* ❖

Asia and Africa Group

Southeast Asia: Dr. Thomas Oberthür

Best Management Practice for Maximum Economic Yield in Mature Oil Palm

Project Leader: Christopher R. Donough, Consultant Agronomist and Oil Palm Breeder, IPNI Southeast Asia Program, Sabah, Malaysia. E-mail: chrisrd@pd.jaring.my

This project was started in 2006 and will continue until 2012 with the main objective of implementing, testing, and refining the Best Management Practice (BMP) concept for yield intensification in order to increase productivity, profitability, and sustainability of palm oil production. BMPs are implemented in five full-size management blocks in six collaborating plantations in Sumatra (North, South) and Kalimantan (West, Central, and East) in existing mature plantings by IPNI and its plantation partners. Results from the BMP implementation are compared to those achieved under standard plantation practices in five reference blocks. At the outset of the research, reference and BMP blocks had similar conditions and performance.

In late 2011, BMP implementation at the six project sites was completed. Yield advantages with BMP were significant at all project sites except one site where current yield is probably close to the site yield potential. Results show the robustness of the BMP concept and its applicability across a wide range of environmental and operating conditions. Bunch yield with BMP averaged 3.4 t/ha (+15%) higher due to more (+9%) and heavier (+6%) bunches. Crop recovery BMPs including a short harvest interval are important for high bunch yield in the short term, while other agronomic BMPs related to canopy and nutrient management are important for sustained or enhanced yield in the longer term. Cost per unit area is higher with BMP, but higher BMP yield improves profitability at the farm gate. In the final year of the project, oil and kernel yields are being estimated. Early indications are that oil extraction rate (OER) with BMP is slightly lower as more frequent harvests result in overall lower number of detached fruits per bunch in the harvested crop. This is not enough to offset the higher bunch yield with BMP harvesting, so oil yield with BMP is still higher. Priorities in 2012 include the full analyses of all data collected. Analyses will be conducted with partner universities in Europe, and possibly Southeast Asia. *SEA-03*

Best Management Practice for Maximum Economic Yield in All Growth Stages of Oil Palm

Project Leader: Chris Donough, IPNI SEAP, Penang, Malaysia. E-mail: crdonough@gmail.com

Project Cooperators: IJM Plantations (Malaysia), Wilmar International, (Indonesia), and Canpotex International

This project was started in 2011 and will continue until 2018 with an objective to implement, test, and refine the Best Management Practice (BMP) concept for yield intensification in order to increase productivity, profitability, and sustainability of palm oil production in all growth stages of oil palm including nursery, immature and mature development phases of the crop. BMPs are implemented in five full-size management blocks in two collaborating plantations in Sumatra (Indonesia) and Sabah (Malaysia) in re-plantings of existing plantations by IPNI and its plantation partners. Results from the BMP implementation are compared to those achieved under standard plantation practices in five reference blocks. At the outset of the research, reference and BMP blocks had similar conditions and performance.

In late 2011, BMP implementation at the Sabah project site had produced about 70% of the seedlings for transplanting into the main nursery. The remaining 30% of seedlings will be produced in the pre-nursery during 2012. In parallel, land preparation for three BMP blocks and three reference blocks had started in late 2011. Transplanting of seedlings from the main nursery into the field blocks is expected to start in the second half of 2012. Currently, the first data are compiled from monitoring of the pre-nursery phase. Databases for the 8-year project are being designed and set up in early 2012. Work on the second site in Sumatra is expected to start in 2012, depending on the replanting schedule of the plantation partner. This project is unique in its design as it is including all growth stages of the oil palm and proposes as monitoring over a period of 8 years. *SEA–04*

Best Management Practice for Crop Nutrition of Mature Oil Palm

Project Leader: Chris Donough, IPNI SEAP, Penang, Malaysia. E-mail: crdonough@gmail.com

Project Cooperators: Sungai Rangit Plantation Indonesia and K + S GmbH, Germany

This project was started in 2011 in one plantation in Kalimantan, Indonesia, and will continue until 2015. The main objective of this experiment is to implement, test, and refine the Best Management Practice (BMP) concept specifically for fertilization and nutrition approaches for yield intensification in order to increase productivity, profitability, and sustainability of palm oil production in mature oil palm plantations. Specific objectives are to: (a) determine the fertilizer recovery efficiency at PT Sungai Rangit—for each input unit of fertilizer applied how much nutrient is taken up by the palms; (b) determine the fertilizer physiological efficiency at PT Sungai Rangit—for each additional unit of nutrient uptake how much additional oil is produced; (c) optimize fertilization strategies for PT Sungai Rangit—fertilizer application amounts, splitting frequencies, adjusted to representative conditions at Sungai Rangit for specific yield targets; (d) demonstrate a repeatable process as to how procedures and nutrient amounts can be adjusted at commercial block scale in low soil fertility production setting to achieve set yield targets; and (e) jointly publish the results of this project upon mutual agreement between IPNI Southeast Asia Program, PT Sungai Rangit, and the K+S KALI GmbH. The ultimate goal will be to enable the use of BMPs for nutrient management to become standard within the industry.

The project will deploy a two pronged approach including commercial block scale implementation of fertilizer management strategies, complemented by block embedded omission plots. Commercial block scale testing of application practices will contribute to more efficient fertilizer application management by the plantation and will contribute information for general fine tuning of nutrient best management practices. Omission plots will generate site specific information about fertilizer use efficiency for the plantation and will be developed into a general tool for plantation nutrient management. We will use 12 commercial blocks. Blocks will be distributed in sets of four within 2 estates of the plantation. Each set of four blocks contains two BMP blocks where fertilizers are applied in 4 splits—one with a high fertilizer rate (BMP 1), the other with a low fertilizer rate (BMP 2), and two reference blocks where all IPNI SEAP BMPs are deployed but fertilizer application follows current standard practice—one with high fertilizer rate (BMP 3), the other with low fertilizer rate (BMP 4). Fertilizers are applied as blended mixes including N-P-K-Mg-B. Omission plots are embedded in 9 of the 12 blocks. Each omission plot contains sub plots for -N, -P, -K, -Mg, -B, and -S, zero and full application. The plot size is a 4x4 palm measurement plot, within a 6x6 palm plot, which is bounded by a trench. The project is currently ongoing, and no specific results are available at this time. *SEA–05*

Plantation Intelligence to Upscale Best Management Practice in Oil Palm, 2011

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This experiment has been planned to start in 2012 through 2015 in several plantations in Indonesia and Malaysia to develop an approach and performance indicators that facilitate up-scaling of the Best Management Practice (BMP) concept from commercial block scale to the whole plantation and to plantation groups. The ultimate goal will be to enable the use of BMPs for yield intensification management to become standard within the industry.

Plantation data on management and specifically on fertilizer use and responses will be sought. Normally this data exists in plantation data log sheets, which can be augmented—after discussion with plantation partners—by additional sites to be managed by them using carefully-designed protocols. Establishing an effective data management system is critical or the database soon becomes unmanageable. We will manage routinely collected plantation production and management information. Once in GIS, data can be analyzed with reference to other geographic data sets. Analysis will include assessment of spatial variations in management practices, including fertilizer use, yield response to management, and to N, P, or K, and return on investment in fertilizer. Block field data will be expanded with model data. Analyses will identify production performance indicators for plantations, and link these to specific BMPs. Analyses will be used to develop a simple process that can be deployed to derive these performance indicators on regular bases. Interpretation will start with a basic set of insights and expand to more detail, leading to site-specific performance indicators. Performance indicators are linked to IPNI SEAP Best Management Practices, and can be generated on a routine bases using data routinely collected by plantations, and thereby are expected to facilitate systematic deployment of BMPs in plantation management.

The general purpose of analysis and performance is to support change towards a more profitable and intensive use of BMPs and fertilizer in oil palm plantations. Key agents of change are plantation managers who can use this process and performance indicators to: (a) make individual and systematic selection of BMPs specific to the local conditions that lead to sustainable intensification of their estates, and (b) communicate with plantation headquarters the certainty of profit from existing or modified applications to obtain specific management support from headquarters. Through this process, estates will be enabled to identify better ways to implement BMPs for yield intensification, on full plantation scale, and across groups of plantations. *SEA–06* ❖

Eastern Europe/Central Asia and Middle East Group

Eastern Europe & Central Asia: Dr. Svetlana Ivanova

Evaluation of Potassium Status of Ukrainian Soils on the Basis of Modern Soil Diagnostic Techniques and Development of Recommendations for the Rational and Efficient Application of Potassium Fertilizers

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Project Cooperators: Khristenko Anatoly, Nosko Boris, Gladkih Ulia, and Istomina Evgenia

In 2011, a three-year project was established in Ukraine with objectives to: a) provide an accurate assessment of K status of arable soils, b) determine the demand for K fertilizers, c) establish the efficiency of K fertilizers in the soils of the main soil-climatic zones, and d) work out fertilizer recommendations for maize, wheat and sugarbeet grown on chernozems based on data obtained by improved methods for a K soil test. Project activities included: a) field experiments on K fertilization for target crops, b) evaluation of soil K status through summarization of database on Ukrainian soil properties and last soil survey, and c) systematic generalization of the data obtained in long-term trails.

Statistical processing of the database on agrochemical certification of agricultural lands and the results of field experiments yielded regression equations for changes in soil K status parameters in different climatic zones of Ukraine. According to the prognosis developed, the average weighted content of plant-available K forms in most Ukrainian soils will remain almost on the natural level corresponding to the average K supply (no more than 8 to 9 mg/100 g of soil) up to 2020.

The results of trials with maize grown for silage showed a high agronomic and economic efficiency of applying K fertilizers to chernozems. The optimization of N and P supply contributes to an increase in the return of K fertilizers on chernozems. A mathematical model was developed for the relationship between the yield of maize green mass and the application rates and proportions of K and NP fertilizers. The highest economic effect was received at the application rate of 90-90-40 N-P_2O_5-K_2O. Similarly, the results of trials with sugar beet showed that the banded application of K fertilizers gave the highest effect on the yield of tubers and the yield of sugar per ha under drought conditions of 2011 while the optimum application rate was 120-120-120 N-P_2O_5-K_2O.

The comparison of the values for the content of plant-available K obtained by different methods showed that the Chirikov method (extraction with 0.5 M acetic acid [CH_3COOH]) recommended and used for routine K soil test in Russia, Ukraine, and Kazakhstan usually overestimates K supply of fine-textured chernozems. *Ukraine-01* ❖

Eastern Europe/Central Asia and Middle East Group

Southern and Eastern Russia:
Dr. Vladimir Nosov

Nutrient Omission Plots in Spring Wheat in Russia: Omsk Oblast and Republic of Bashkortostan

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Project Cooperators: I.F. Khramtsov and F.Ya. Bagautdinov

The following fertilizer treatments were applied in the Republic of Bashkortostan (N-P_2O_5-K_2O in kg/ha): 1) control, 2) 10-10-10, 3) 150-25-28, 4) 150-25-0, 5) 150-0-28, 6) 6-25-28. Spring wheat was the third crop after fallow in this location (after winter rye and buckwheat). The highest grain yield of 3.49 t/ha was obtained with recommended application of N, P, and K (treatment 3). N, P, and K fertilizer use increased grain yield by 0.52 (18%), 0.28 (9%), and 1.09 (45%) t/ha, respectively. Initial soil properties indicate low nitrate level in the soil. It was assumed that favorable conditions (temperature, rainfall) for N mineralization from soil organic matter occurred during 2011 growing season resulting in the moderate efficiency of N application. Somewhat low response to P fertilizer was likely because of "increased" content of P extracted by a routine soil test (0.5 M acetic acid [CH_3COOH]) and also high content of Olsen P according to soil test interpretation classes proposed by researchers in Russia. This leached chernozem in the Republic of Bashkortostan had an "increased" content of K extracted by a routine soil test (0.5 M CH_3COOH) but a low content of exchangeable K. Thus, K fertilizer application was very effective in increasing yield.

The fertilizer scheme in Omsk Oblast was as follows: 1) control, 2) 10 kg N, 3) 96-82-30 kg N-P_2O_5-K_2O, 4) 96-82 kg N-P_2O_5, 5) 96-30 N-K_2O, 6) 82-30 P_2O_5-K_2O. The third spring wheat after fallow was grown in this location. The highest yield of grain of 3.09 t/ha was again obtained with the recommended application of N, P, and K (treatment 3). Nitrogen, P, and K fertilizer use increased grain yield by 0.98 (46%), 0.04 (1%), and 0.06 (2%) t/ha, respectively. The effect of P and K applications was not significant. This leached chernozem in Omsk Oblast had a medium content of P extracted by a routine soil test (0.5 M CH_3COOH) but an "increased" content of Olsen P. The latter may explain why P fertilizer application to spring wheat was not effective at increasing crop yield at this experimental site. K fertilizer use was also not effective at increasing yield because of the very high content of K extracted by a routine soil test (0.5 M CH_3COOH) and also a very high content of exchangeable K. *IPNI-32* ❖

Eastern Europe/Central Asia and Middle East Group

Middle East

Dr. Munir Rusan

Balanced Fertilization of Major Crops in Egypt

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In Egypt, application of mineral fertilizers is highly skewed towards N, which has lead to the depletion of other nutrients like K, P, and micronutrients in many soils. The objectives of this project were to: (1) determine the effect of balanced fertilization on the yield of major crops of the common cropping systems in Egypt, and (2) promote and extend to farmers the most efficient fertilization and irrigation techniques. For this, field experiments were conducted at three locations with the following seven treatments: (1) no fertilizer, (2) NPK according to the farmer's practice, (3) NP at the recommended rate, (4) NK as recommended by Egyptian Ministry of Agriculture (MoA), (5) NPK as recommended by the MoA, (6) NPK based on soil testing, and (7) NPK Based on soil testing + micronutrients.

For all crops and at all three locations, balanced fertilization helped maximize yield and yield components. At El-Behira, wheat grain yield was the highest (7.8 t/ha) for the NPK+micronutrients treatment, whereas control and the farmers' practice resulted in the lowest yields (2.4 and 4.2 t/ha, respectively). A similar trend was observed in maize, where the highest yield (9.1 t/ha) was obtained with the NPK+micronutrients, while control and farmers' practice gave 2.8 and 5.1 t/ha, respectively. Similarly, at El-Monofia, wheat grain yield was the highest (7.9 t/ha) for the NPK+micronutrients treatment, while the control and the farmers' practice resulted in the lowest yields (3.1 and 4.3 t/ha, respectively). Once again the maize crop recorded the highest yield (12.6 t/ha) with NPK+micronutrients, while the control and farmers' practice recorded 6.3 and 9.0 t/ha of grain yields, respectively. Similar results were obtained at Ismailia, where yet again the wheat grain yield was the highest (6.25 t/ha) with NPK+micronutrients application, while the control and the NP treatments resulted in the lowest yields (1.0 and 3.7 t/ha , respectively). For fodder sorghum crop, the highest yield (89.7 t/ha) was again obtained with the NPK+micronutrients, while the control and NP treatments had 4.9 and 45.5 t/ha yields, respectively. *Egypt-01*

Balanced Fertilization of Major Crops in Syria

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Project Cooperator: Ali Zaidan

In Syria, application of mineral fertilizers is highly skewed towards N, which has lead to the depletion of other nutrients like K, P, and micronutrients in many soils. The objectives of this project were to: (a) determine the effect of balanced fertilization on the yield of major crops of the common cropping systems in Syria, and (b) promote and extend to farmers the most efficient fertilization and irrigation techniques. For this, both on-farm and on-station experiments were conducted at four different locations in Syria with different permutations and combinations of macronutrients (NP, NK, PK, NPK, etc.) and fertilizer rates varying from 75 to 150%. This summary provides results from just one location in Southern Syria (Dera's Azrou).

The results obtained from the wheat experiment conducted at a farmer's field in Southern Syria (Dera'a Azrou) indicated that the highest wheat grain yield (2.31 t/ha) was obtained when all three macronutrients were applied at 72, 38, and 35 kg/ha of N, P_2O_2 and K_2O, respectively. In contrast, the lowest grain yield (1.73 t/ha) was obtained when no fertilizers were added, while no significant differences were observed among

other treatments. Interestingly, however, the on-station research did not yield any significant differences among any of the treatments except the one where no fertilizers were applied, which gave the lowest wheat grain yield of 2.35 t/ha. Results from other sites are being compiled. *Syria-01* ❖

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